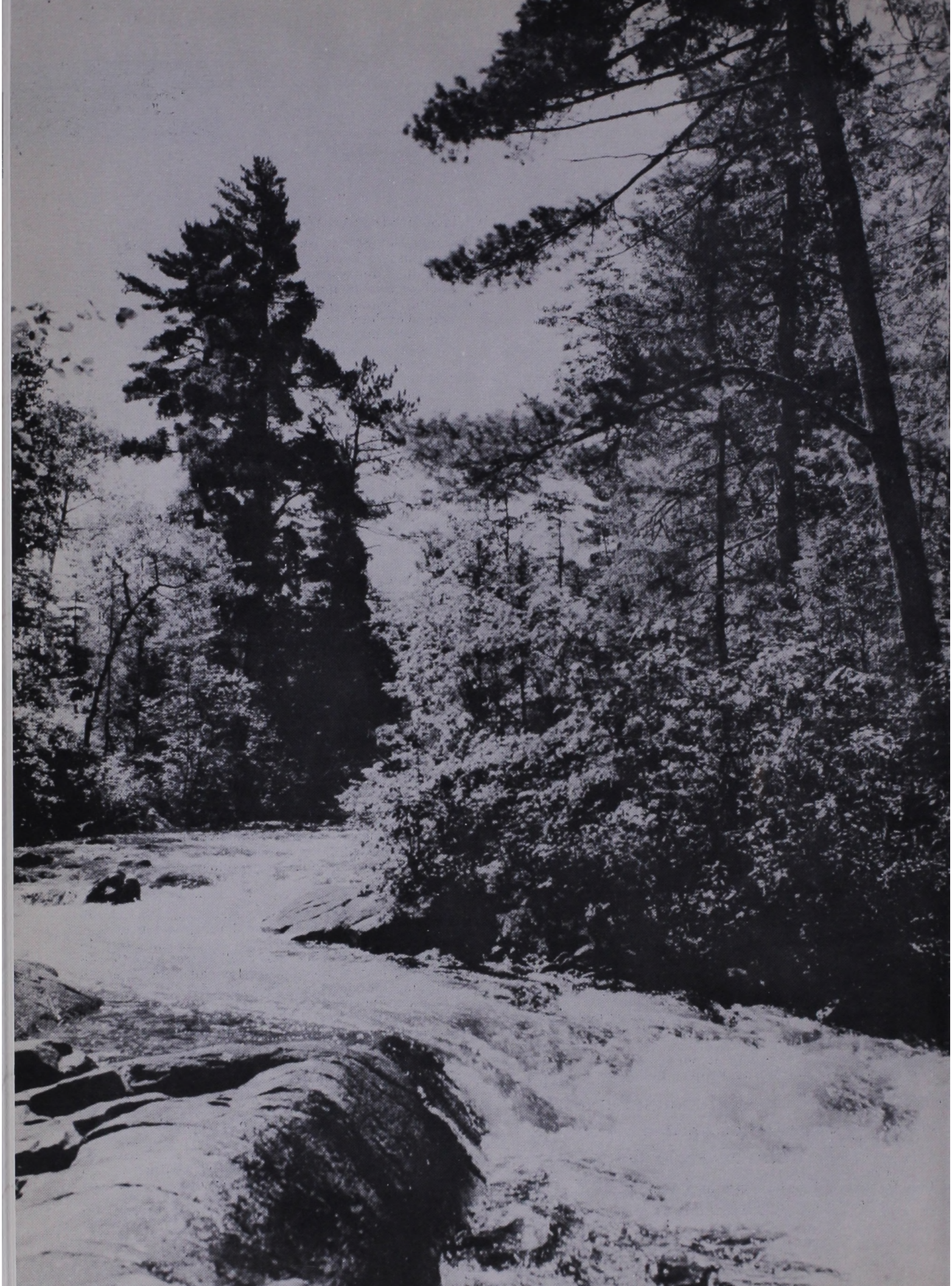
1962

40th

ANNUAL REPORT

Lake States Forest Experiment Station

OREST SERVICE • U. S. DEPARTMENT OF AGRICULTURE



FORTY YEARS OF FOREST RESEARCH

This is the 40th Anniversary of the Lake States Forest Experiment Station. Established in 1923 and located from the start on the St. Paul Campus of the University of Minnesota, the Station is now a recognized regional authority and center of information on the scientific basis for managing forest and related wild land resources. Much of the Station's research is done in cooperation with forestry schools, State forestry organizations, and forest industry.

Beginning with a staff of five, the Station was faced with a wide array of urgent problems. Forest fires were burning well over 1 million acres annually. The lumber industry was dwindling as old-growth timber ran out. There were no reliable data on the extent or kinds of forest types and on timber volume, growth, and drain. And almost nothing specific was known about the inter-relation of forests to water, wildlife, and recreation. Interest in shelterbelt plantings was high in the Northern Plains but, because of insufficient knowledge of what and how to plant, many early shelterbelts failed. Research in forestry was a remote subject. The needs and opportunities were great.

It was in this situation that the Station pioneers went to work. Their triumphs and discouragements were numerous. They suffered the usual frustrations of any research group, plus those peculiar to forestry. Experiments were destroyed by wildfire. Others yielded fewer reliable data than expected because of the primitive state of knowledge of experimental design. Shortage of funds and lack of manpower at times forced discontinuance of some studies. But the gradually increasing interest in research by the public, State forestry organizations, and forest industry provided the much needed encouragement to get on with the job. Some of the more newsworthy events in the ensuing years are mentioned briefly here.

By the midthirties the forest area burned annually had been reduced to about a quarter of a million acres. This was the result of an intensive cooperative effort in which the Station played an important role through collecting and analyzing weather and fire data and advising the fire suppression agencies through publications and consultations. The results of the Station's research crystallized in the Lake States Burning Index Meter which rates current fire hazards. It is still used widely today.

An inventory of Lake States forest resources began in 1933 under the leadership of the Station, and by 1940 the first regionwide inventory had been completed. This proved so valuable that periodic forest inventories every 10 years or so are now a regular part of the Station's plans.

Forest management studies were an important part of the Station's program from the beginning. Over the years hundreds of research reports appeared. Among the most important were bulletins on the management of natural stands of red pine, jack pine, black spruce, and northern hardwoods. Research on seed handling and nursery practice, planting, and the care of plantations contributed substantially to the success in establishing over 2 million acres of plantations to date.

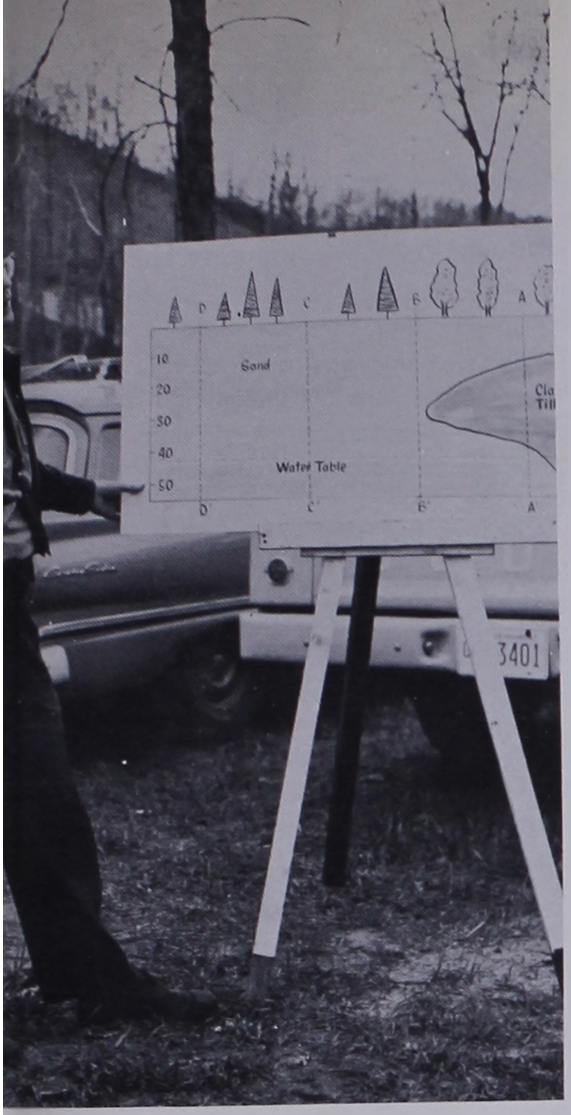
During the thirties, numerous studies were begun on flood and erosion control under the direction of Carlos Bates. Some of these studies have been useful guides in public programs. Others have been the basis for a more intensive research effort in watershed management. Work in the sandhills of North Dakota on shelterbelt problems enabled the Station to provide technical guidance on the Prairie States Forestry Project. S. R. Gevorkiantz, internationally known mensurationist and statistician, was in a large measure responsible for developing volume, growth, and yield tables, which are the basis for measuring Lake States forest production. Russell Cunningham, a pioneer leader in forest economics research, initiated numerous studies dealing with low income in forest areas and did much to bring about an understanding of the new public domain which was coming into existence because of tax delinquency.

FIGURE 1. — Scenic spots such as this, plus a wide variety of outdoor recreation opportunities, draw thousands of visitors to the northern Lake States each year.

DEDICATION TIME .

at the Northern Hardwoods Laborat

Marquette, Mich



at the Udell Experimental Forest

Wellston, Michigan

FIGURE 3. — The Udell Experimental Forest near Wellston in Lower Michiga was also dedicated in 1962. In the group picture from left to right are M. I Dickerman, Director, Lake States Forest Experiment Station; Clark Holscher, Assistant Chief, Division of Watershed Management and Recrea tion Research, Washington Office; W. David Striffler, Leader of th Station's Ground Water Hydrology Project; Louis Pommerening, Super visor, Lower Michigan National Forest; Gerald Eddy, Director, Michiga Department of Conservation; and Dwight Spuller, Secretary, Michiga Soil Conservation Districts. Pictured at left, discussing Udell hydrolog problems, is Dean H. Urie, a scientist on the project.

With the upsurge of interest in research following World War II, the Station's program broadened. Forest insect and disease research became a Station responsibility. New programs were established in watershed management, forest utilization, marketing, engineering, genetics, and soils. Certain phases of shelterbelt work were again undertaken. With the buildup of strong fire control organizations in the States and the reduction in fires, research in fire prevention and control, conducted so ably by Jack Mitchell, decreased. But changing forest conditions required new fire studies, primarily in plantation areas and in the beneficial use of fire. Heavily increasing interest in forest recreation and wildlife habitat resulted in the establishment of research projects in these two fields (fig. 1). Rising forest land values demanded more knowledge about the objectives of forest owners, the economics of growing timber, and forest taxation.

FIGURE 2. — Dedication day at the Northern Hardwoods Laboratory, Marquette, Mich. Here research in the silviculture and diseases of northern hardwoods is conducted.

Along with this broadening in scope came an increased emphasis on basic research. A clear understanding of the fundamental factors that influence forest regeneration and growth, the biology and ecology of insects, the life cycles of forest diseases, the hydrology of forest swamps, and the social factors involved in forest recreation — all these and many others became areas of research in a broadened Station program.

As time has passed, the organization has shifted so that new activities and responsibilities could be handled effectively and promptly. There are now 11 field offices in 4 States. Each of these, under the guidance of the St. Paul headquarters, is responsible for one or more research projects. With the establishment of these field offices, the emphasis on basic research, and the addition of specialists (entomologists, pathologists, physiologists, engineers, soil scientists, and social scientists) to the staff, well-equipped laboratories were essential. In 1960, laboratory buildings were completed at the Institute of Forest Genetics, Rhinelander,

Wis., and the Silviculture and Watershed Laboratory, Grand Rapids, Minn. In 1962, the Northern Hardwoods Laboratory in Marquette, Mich., was dedicated (fig. 2). A Shelterbelt Laboratory at Bottineau, N. Dak., is under construction. Then, in August 1962, ground was broken for a new Station headquarters and laboratory building in St. Paul.

In 1962, significant additions to the Station's program consisted of a marketing research unit on the Duluth Campus of the University of Minnesota, and the Udell Watershed Experimental Forest near Wellston, Mich. (fig. 3). A new Pioneering Research Unit, the second in the United States, was established at Rhinelander, Wis. There, Dr. Philip Larson is directing studies on the physiology of wood formation.

With all this activity at the Station we feel the impact on our forest resources has been considerable. In 1923, the fund of forestry knowledge was small, the number of researchers were few, and the general public was just beginning to stir from apathy toward conservation. In 40 years, knowledge on how to grow trees has increased enormously, many of the public agencies and the large forest owners have instituted good forest management practices as we know them today, and a large proportion of the public is aware of forest needs. Multiple use of forest land is being recognized as a "way of life," and greater emphasis is now placed not only on timber yields but also on water, wildlife, and recreation — all products of a forest environment. Our forests are now mainly in the sapling and pole stage of growth and are far better stocked than even 20 years ago. The potential for maximum productivity is there for us to work with in the years ahead. It remains to be seen how close we can come to attaining it.

Turning now to the material presented in the following pages — our Annual Reports can no longer give a comprehensive review of all activities because of the breadth of the Station's program. However, in this 40th annual report some of the recently completed projects and some of the projects installed within the past couple of years are discussed. A list of publications at the end of the report is also informative on what the Station was doing in 1962. Two of these are major bulletins summarizing several years' work in two fields: The Growth and Yield of Red Pine, by Dr. Robert Buckman; and Shelterbelt Influence on Great Plains Field Environment and Crops, by Dr. Joseph Stoeckeler.

FOREST RECREATION AND WILDLIFE HABITAT

Land use planning in the northern Lake States is being influenced increasingly by forest recreation. Growing numbers of visitors present challenges to planners, especially if quality of recreation is not to be lowered. More visitors present opportunities to private businesses, which are particularly welcome in an area with underemployment problems; and efforts are being made to encourage further increases in use. Many proposals have recently been advanced for new recreation area developments on lands of all ownerships. States have employed more specialists to encourage this effort. New campgrounds, roads, and trails will be provided under the accelerated public works program begun in 1962. In this atmosphere of heightened activity the Station has moved rapidly ahead with outdoor recreation research, begun in 1960.

A subject of much interest to a large proportion of visitors to the forest is its wildlife. But as the area of wildland shifts, it becomes more and more essential to understand the mutual relationships between wildlife and its habitat and to know the effects of various forest management operations on such habitat. The emphasis in this field of study is therefore being directed toward these goals.

A Cooperative Recreation Research Unit in Michigan

Research on forest recreation, like research on timber production, needs to draw on knowledge and skills in many fields of learning. To help stim-

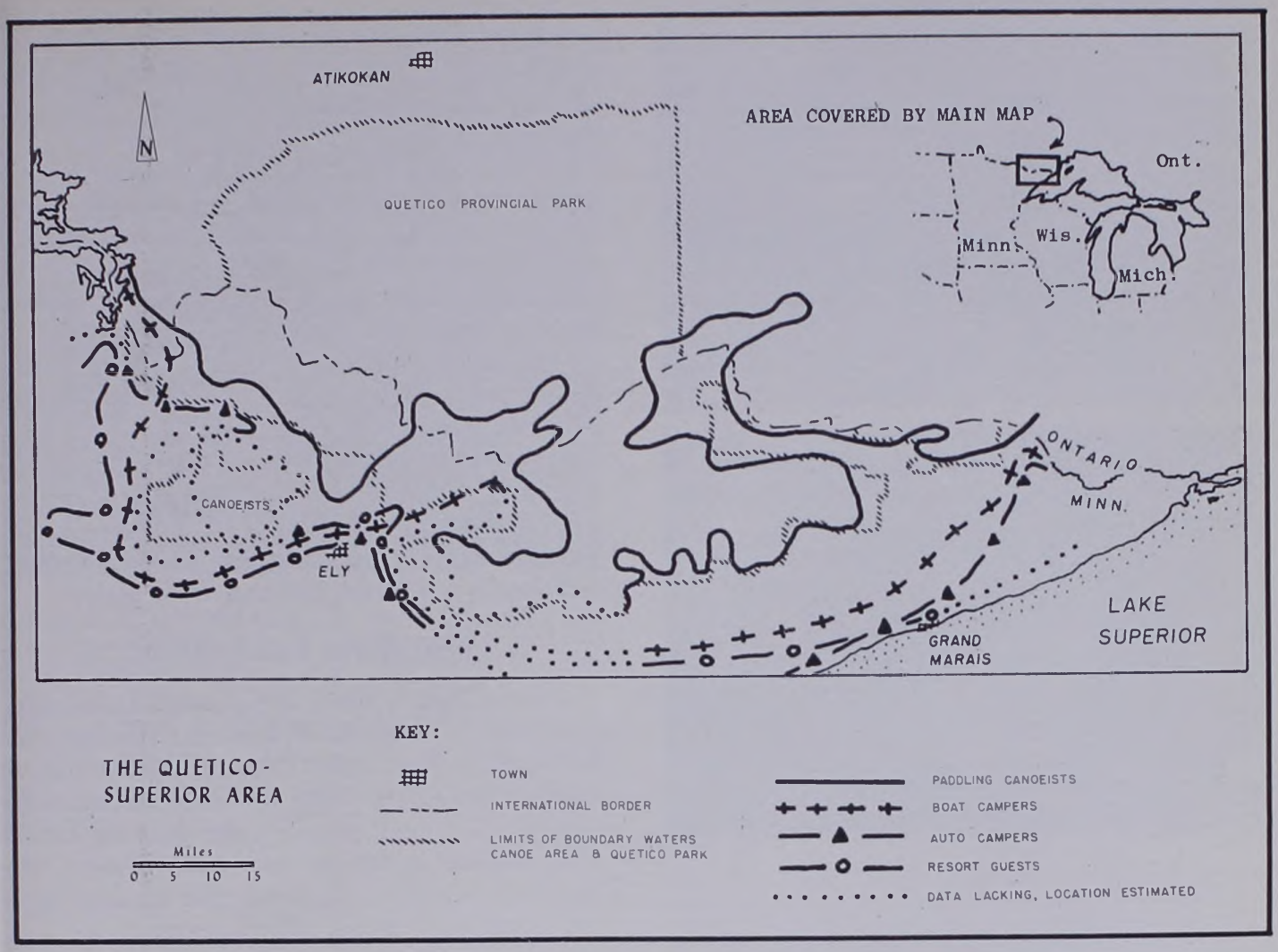


FIGURE 6. — The areas considered "wilderness" by at least 50 percent of four major user types. The area to the north of the lines drawn for each type was viewed as wilderness; the northern limit of the wilderness was not studied. Note the large area which was wilderness for all of the types except canoeists. Also note that most of the canoeists travelling in the central part of the Boundary Waters Canoe Area excluded it from their wilderness.

by research anywhere, and sequential observations are nonexistent. All of the sample plots have been carefully located, measured, and photographed, and rechecking will be done in the future.

Use on Lower Michigan National Forests

From the remote, relatively lightly used Canoe Country to the fringe of the urban Middle West — this is the recreational range in the Lake States. Work shifted from the first extreme to the second in 1962. Two studies were begun, with a combined field survey to collect data for both. The fieldwork involved 933 interviews with recreationists on the Lower Michigan National Forests. Of this number 556 were campers and the remainder were other kinds of users. The response of the people to the interviews was above our expectations. The objectives of these studies are discussed below.

How Do Locational Factors Affect Use?

A large investment in new and expanded forest recreation sites will probably be made in the near future. Poor locational decisions will be costly. Existing and potential Forest Service sites were inventoried in detail as part of the National Forest Recreation Survey in 1959, but better plans could be based upon this inventory if more was known about the relationship of the amount and type of use to the qualities of the site and to its relative locational characteristics.

This is the central question of the first Michigan study. Estimates of selected types of National

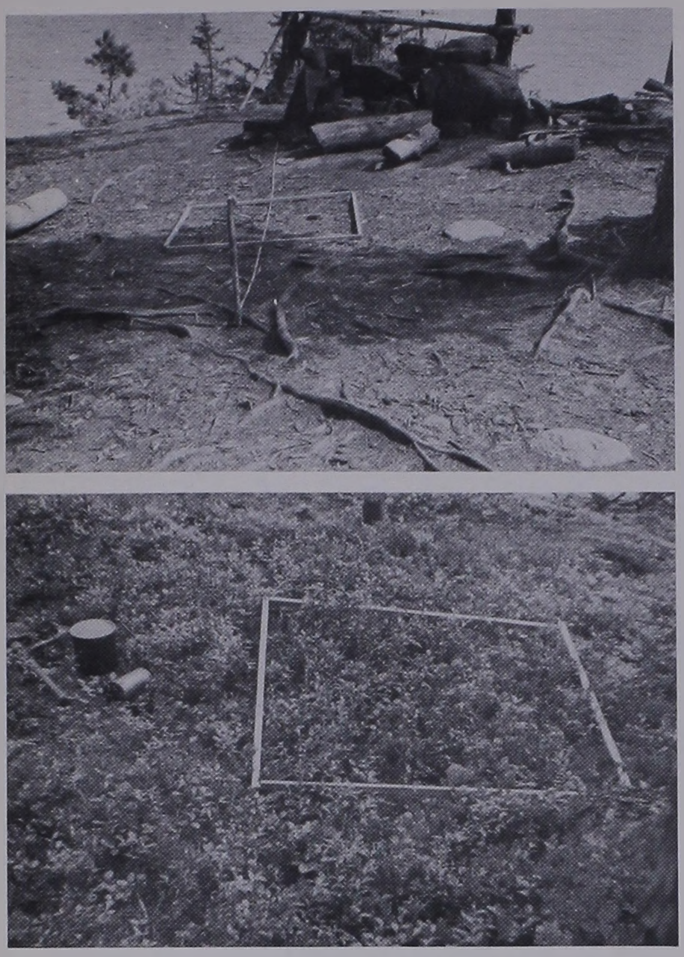


FIGURE 7. — Two plots only 35 feet apart show the extent of environmental change caused by camping. In the top picture roots are exposed and low vegetation completely destroyed on a typical campsite deep in the canoe country but on a popular route. In the bottom picture vegetation is growing undisturbed.

Forest recreational use will be developed from an intensive sample head count. First impressions suggest that swimming beaches account for most of the variation in campground use. Location close to highways may be the main variable associated with the other uses.

Reactions to crowding were also studied, but this appears to be much less a problem than in the Canoe Country.

How Do Personal Factors Affect Use?

The second study of recreation on the Lower Michigan National Forests is a socio-economic study of family campers. While considerable information is available on a national basis, little is known about the characteristics of recreational users of particular National Forests or of specific kinds of users.

The objectives of the study are:

1. To describe the social and economic characteristics of family campers on the Lower Michigan National Forests and to compare these to those of the general population within the Forests' camping market area.

2. To determine which factors are significantly related to the amount of camping done by family campers during the summer season. The results of the study should show which factors should be considered in future recreation market surveys made as bases for projections of camper use.

Although tabulation is now in process, some results are already apparent. The Lower Michigan National Forests draw campers primarily from nearby Michigan urban places. The campers are primarily middle class in education and income. This is in contrast to the Superior National Forest where education and income levels were higher and people had traveled farther from home.

Porcupine Food Habits

During 1962, a study of porcupine food habits, conducted in cooperation with the University of Michigan, was completed. Results showed that in summer, porcupines feed primarily on leaves of woody plants and restrict their gnawing to old logs, deserted buildings, and similar objects. The shift from a leaf to a bark diet does not occur until the leaves begin to fall. Where the porcupine population was approximately 40 to 50 per square mile, they had fed on the bark or twigs of approximately 5 percent of the trees cut in a commercial operation. Since deformed trees had been marked to improve the stand, it is probable that the percentage of the remaining trees attacked was somewhat smaller. This included feeding injury to twigs of elm as well as bark feeding on sugar maple, hemlock, yellow birch, and basswood.

Many of the tops showed feeding over a period of several years, indicating that the animals tend to return to the same trees year after year (fig. 8). Thus, with a stable porcupine population, only a small number of undamaged trees are likely to be gnawed for the first time in any given winter.

Deer Browse Study

To date, a study of deer browse conducted in cooperation with the Wisconsin Conservation Department shows that managed second-growth hardwoods in Wisconsin with an overstory of 75 square

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FIGURE 8. — A yellow birch tree with a porcupine den that shows years of use. Robert Brander, University of Michigan graduate student, examines the den while making a porcupine food habit study.

feet of basal area per acre are producing 10 times as much deer food as are uncut stands. This is due both to the increased production per stem (about four times as great) and to the greater number of browsable stems (almost 2½ times as many) in the thinned stand. However, the annual yield of browse is still very low, amounting to only about 21 pounds per acre in cuttings with a good stocking of reproduction. A similar trend was also evident in old-growth hardwoods in Upper Michigan where a stand cut to 90 square feet produced only one-third as much browse as did one cut to 50 square feet of basal area. Overall yield of browse in the cutover old-growth was only about half as great as that in the thinned second-growth stands.

The most important browse plants in Wisconsin were sugar maple and white ash; in Upper Michigan, sugar maple alone produced the bulk of the available browse. At the same time, a considerable amount of the yield was furnished by such pioneers as red elderberry, hazel, and black cherry. With less than 10 percent of the stems, these three species produced over 15 percent of the browse in the cuttings, showing the great importance of the pioneer species in browse production. Road and swamp edges and openings where pioneer species thrive may thus be tremendously important in the total food picture.

FOREST MANAGEMENT

When the Station began operation in 1923, most of the emphasis in forest management research was on growth studies and silviculture. As forest practice has advanced, the need for new and specific knowledge has kept pace. Our work has therefore been broadened considerably. Not only have new fields been added, but the work in others has become more comprehensive. Thus, as we enter our 40th year of public service, we are expanding work in lines which were barely thought of back in the 20's. Among these are forest genetics, tree physiology, and site requirements.

In other lines of work, studies begun many years ago are now paying large dividends. For example, the bulletin on growth and yield of red pine, published in 1962, is based on 235 permanent sample plots, some established as early as 1926. Since this study involved some 320 measurement periods, we were able to present a more complete picture of growth and yield than has hitherto been possible.

As a result of the growth in depth of the forest management research program, we not only are studying in more major problem areas, but the methods are more precise and the studies more exhaustive. This is well brought out in the following section, which discusses the major results obtained during the past 2 years from typical studies in forest management research.

Forest Genetics

Resistance to Winter Injury in Pine Hybrids

That resistance to winter injury in hybrids and backcross progeny resulting from crosses of jack pine (*Pinus banksiana* Lamb.) and lodgepole pine (*P. contorta,* Dougl.) is a characteristic controlled by multiple factors or polygenes is shown by observations made during May 1959 in a test planting on the Argonne Experiment Forest, northeastern Wisconsin (fig. 9).

Native jack pine showed no foliage injury, but lodgepole pine suffered injury to more than two-thirds of its foliage (fig. 10). The first-generation hybrids, on the other hand, had injury intermediate between that of their two parents. Likewise, the progeny of the backcross to jack pine showed injury intermediate between that of the first-generation and the recurrent parent, indicating multiple-factor inheritance of this character. Although the source grown from seed collected in a plantation of the F_1 hybrids (No. 2528) shows greater average injury than would be expected in the F_2 generation (normally the average injury would be similar to that in the F_1), this inconsistency may be a chance occurrence resulting from the small number of F_2 trees observed.

FIGURE 9. — Paul Rudolf examines a jack pine-lodgepole pine hybrid for winter injury.

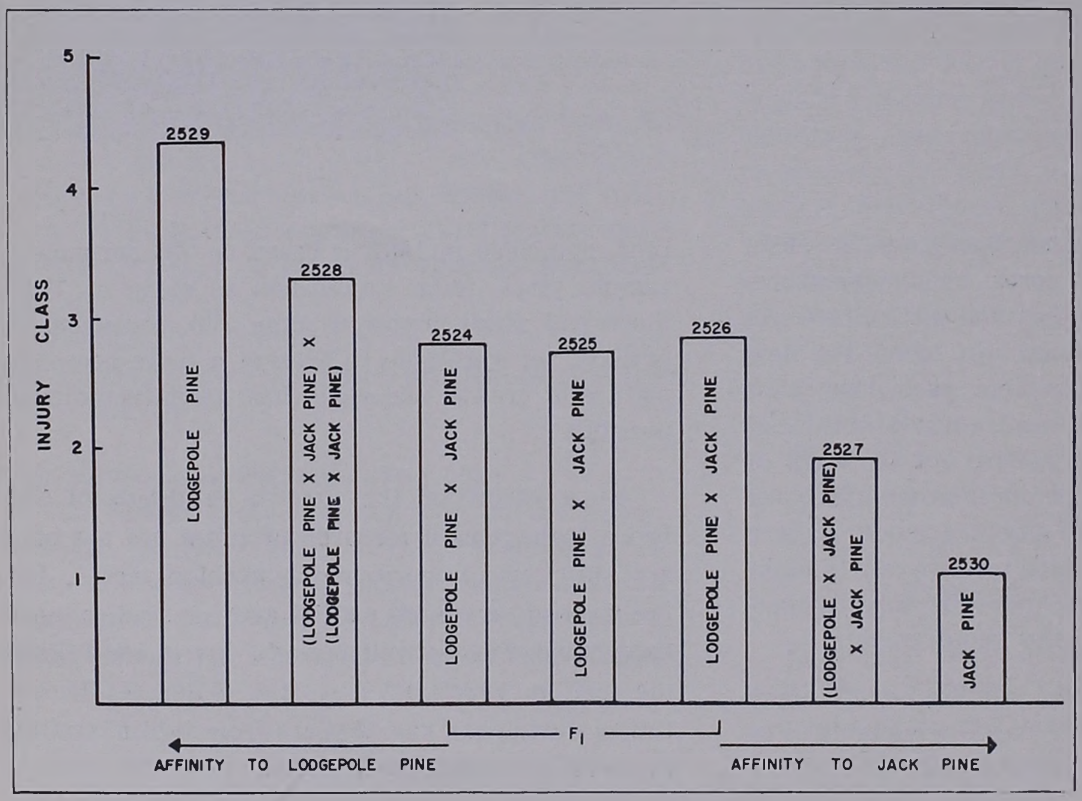

FIGURE 10. — Relative winter injury to lodgepole pine and jack pine and their F_1, F_2, and backcross progeny. Means were computed from the following individual tree classifications: 1 — no injury; 2 — less than one-third of foliage injured; 3 — one-third to two-thirds of foliage injured; 4 — more than two-thirds of foliage injured; 5 — total injury or dead. The lodgepole pine represent three elevations, 6,100 to 7,300 feet, on the Eldorado National Forest, Calif. The jack pine was from Wisconsin.

These results indicate that future breeding must be through the use of the backcross method, eventually leading to a hybrid combining winter hardiness with other desirable characteristics of both parent species. Thus, lines could be developed that would be suitable for planting in environments tolerated only by the hardier parent.

This study is only a small part of the genetics program with northern species now in progress at the Institute of Forest Genetics at Rhinelander. In jack pine the program includes studies of vigor, lammas growth and prolepsis (see Annual Report, 1960), resistance to the needle cast fungus (*Hypodermella ampla*), and other silviculturally important charactertistics. Native and exotic spruces are also being studied intensively, and a program with the genus *Betula* was begun during the past year.

Tree Physiology

Factors Influencing Tracheid Diameter

In previous annual reports describing our work on the earlywood-latewood transition in red pine, it was stressed that tracheid diameter was controlled by the activity of the terminal meristems. Thus, it was found that large-diameter earlywood cells were produced when terminal growth was active, and a transition to narrow-diameter latewood cells occurred when terminal growth declined or ceased (fig. 11). These changes, occurring during the normal season of growth under natural conditions, have also been artificially produced by controlling the photoperiod. Terminal activity and earlywood cell production were prolonged by long-day treatment, whereas terminal activity ceased and latewood cell production was initiated by short-day treatment (fig. 12). Under the conditions of these experiments, however, it was impossible to determine the relative contribution of the buds and the needles to overall terminal activity and subsequent xylem cell diameter. More recent work has, therefore, attempted to make this distinction and to determine by various procedures the independent contribution of the buds and needles to tracheid diameter under the influence of varying photoperiods.

From the data of the latest experiments, it has been concluded that the bud or apical meristem has a decisive regulatory influence on cell diameter during the period of active extension growth of the shoot. But, when extension growth terminates and primordia are being laid down in the formation of a new bud, the influence of the bud declines and the elongating needles instead become the principal source of the stimulus contributing to cell diameter.

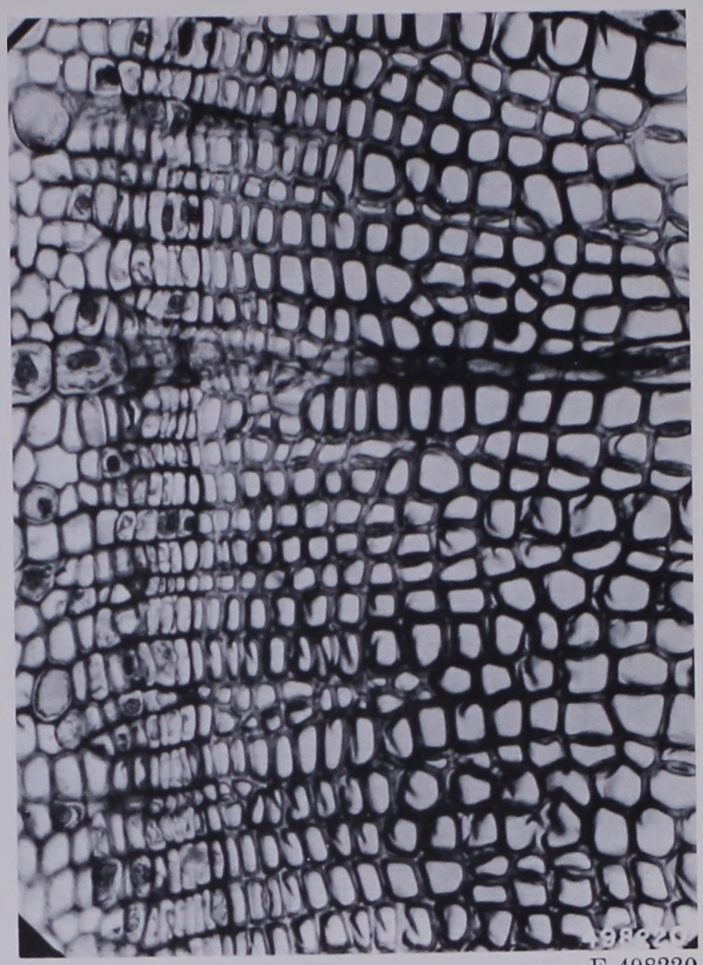

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FIGURE 11. —When the days are long, trees make considerable terminal growth and cells of large diameter (earlywood) are produced *(right)*. As the days shorten, terminal growth ceases and the diameter of the cells decreases. This is shown by the latewood toward the left side of the photograph.

The influence of photoperiod on tracheid diameter appears to be indirect. Photoperiodic perception is in the vegetative organs of the tree, and the stimulus arising from the photoperiodic-induced activity within these organs is transmitted to the differentiating xylem cells. Experimental evidence has been presented previously supporting the hypothesis that the stimulus regulating tracheid diameter is a plant hormone (auxin) originating in the terminal shoots and that the size of any individual tracheid will be determined by the amount of auxin reaching that cell at the time of differentiation. Thus, the influence of

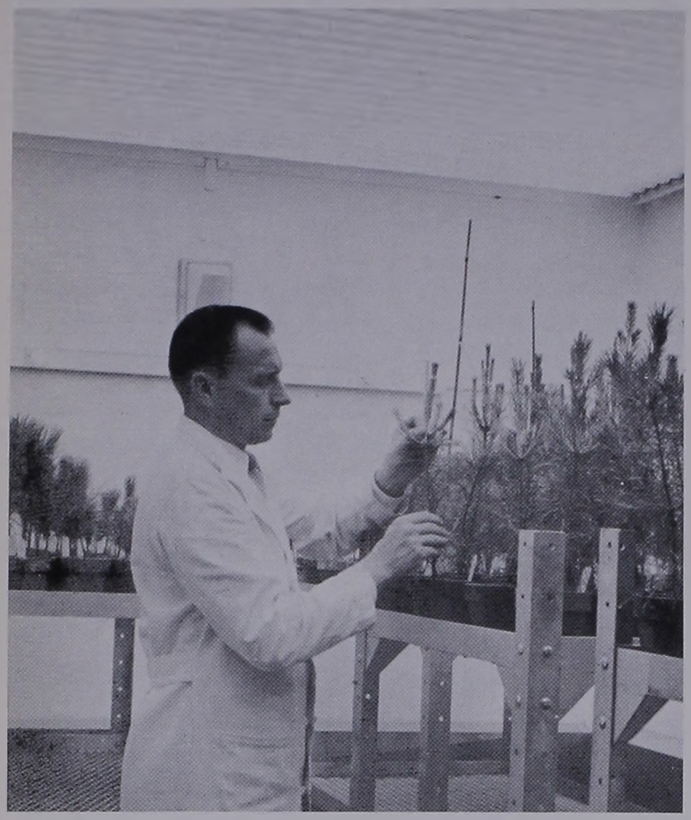

FIGURE 12. — Controlled daylength affects the stem growth of seedlings. Dr. Philip Larson measures the height of young jack pine being grown under long-day conditions.

photoperiod is directly related to the synthesis of auxin and only indirectly related to the auxin-regulated changes in cell diameter.

A similar indirect relationship was found between the formation of latewood and drought in young red pine trees. When trees with actively elongating needles were subjected to drought conditions, needle growth immediately slowed down and a corresponding decrease in tracheid diameter occurred in the stem. Rewatering of the trees was followed by a resurgence of needle elongation and an increase in tracheid diameter. A false ring could, therefore, be artificially induced in the stems of these trees by subjecting them to drought and subsequent rewatering. If two drought periods were imposed during the growing season, two false rings could be produced. In every case, narrow-diameter cells were produced during the drought period when needle growth declined and large-diameter cells during the period of rewatering when needle growth was active.

As in the case of photoperiodic treatment the influence of drought on tracheid diameter was found to be indirect. The direct effect of drought was on needle growth and consequently on auxin synthesis. The decreased tracheid diameter during drought treatment must, therefore, have been due to the decreased auxin synthesis, since it is believed that auxin is the primary factor controlling cell size.

Site Requirements

Much of our past research has dealt with the reaction of forest trees to factors of their environment. A tree species grows better on some soils than on others. Competition from associated vegetation is critical in some places and not in others. One tree species may react quite differently from another to a set of conditions that we know as local environment, including soil type, temperature regime, precipitation pattern, and topographic location. Bringing together sufficient information on factors of environment to permit a biologically sound basis for classification of forest sites is a large undertaking. This is our ultimate goal. We're still in the stage of accumulating information on the significant factors and their range of influence.

Requirements of Paper Birch

The principal factors determining site in paper birch in northern Wisconsin are terrain, the amount of fine particles (silt-plus-clay) in the top 6 inches of soil, and the surface drainage. The best sites were areas with gentle slope (less than 10 percent or, if steeper, involving an elevation change of less than 15 feet), a silt-plus-clay content of more than 10.5 percent, medium-to-good surface drainage, and a mottled subsoil within 4 feet.

On the basis of the growth and yield of this species on the different area classes, preliminary recommendations for management have been made. On the best sites (Area Class III) paper birch can be managed for sawlogs and veneer on an 80-year rotation. On the poorest sites (Class I) it should be cut for pulpwood at about 60 years.

Mineral Elements in Black Spruce

Currently, studies are being made of nutrient conditions in certain areas of the extensive black spruce bogs in northern Minnesota. Ecological research conducted by the northern conifer project at Grand Rapids has indicated that site quality for growth of black spruce is obviously influenced

by the drainage pattern. Areas of relatively rapid water movement "downstream" from upland islands in the peat produce stands of pulpwood size; with increasing distance laterally from these "water tracks," the stands rapidly change to sphagnum muskeg that will not even grow spruce suitable for Christmas trees. Investigation of peat depths, water table levels during the year, and temperatures above and below the peat surface does not explain satisfactorily these site changes. One possible explanation is the movement of inorganic nutrients from the islands "downstream" into the swamps, thus resulting in better growth of the stands in the enriched areas.

Analysis of foliage is an accepted technique in the study of mineral requirements of plants; this method is being used to study the availability of mineral elements in such bogs.

At the end of the 1961 growing season, foliage samples were collected on the Big Falls Experimental Forest and analyzed for 12 elements by the spectrographic laboratory of the Horticulture Department of Michigan State University. Results of the analyses of 110 trees on three transects running from the good site in the water track to the poor-site muskeg show that nitrogen and phosphorus levels of the foliage are related to site index. Levels of these two nutrients are low on the poorest site investigated, site index 20, but increase with increasing site quality until the best site index of 60 is reached in the water track itself (fig. 13). The other 10 elements analyzed did not show any well-defined trends with site quality but are valuable as an illustration of the nutrient levels, especially for the seldom investigated trace elements such as boron, copper, and molybdenum that may be found in natural stands of black spruce.

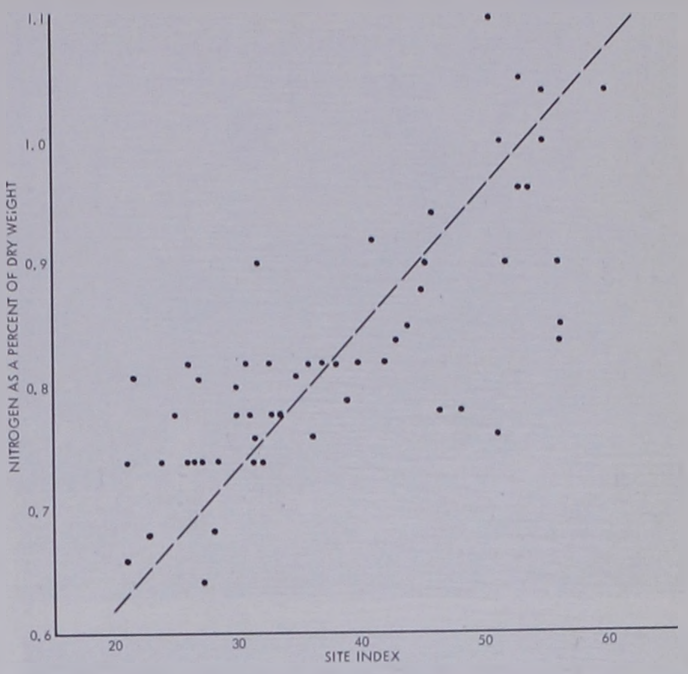

FIGURE 13. — Scatter diagram of percent of nitrogen of black spruce foliage over site index.

Northern Hardwoods Silviculture

Major progress in the northern hardwood silviculture project was made during 1962 toward working out the seedbed requirements of our most valuable hardwood, yellow birch. A study of marking methods in second-growth hardwood pole stands is also reported here.

Yellow Birch Seedbed Requirements

In the northern hardwood type, sugar maple tends to increase its proportion at the expense of the less aggressive but more valuable yellow birch. Preliminary studies in both Canada and the United States have indicated that an unfavorable seedbed is the primary cause of poor regeneration in this species but other factors such as light and moisture also play a large role.

To learn more about the relative importance of these three factors, blocks of seedbed were cut from eight kinds of forest floor and transported to a central area with a shallow water table (fig. 14). There they were laid in rows in the open and under plastic screen which reduced light to 30, 50, and 75 percent. In addition, the subsurface moisture was controlled on half of the blocks by lining trenches with plastic sheeting and laying the seedbeds on top of the plastic. Here the water level was maintained a half foot from the surface; elsewhere it was allowed to fluctuate naturally.

Yellow birch was seeded during the fall of 1961. Germination was counted at short intervals throughout the summer of 1962, causes of mortality were estimated, and height growth recorded. Preliminary analysis of the first year's data shows some interesting trends.

Germination in the open was very poor regardless of moisture conditions; it was better under moderate and heavy shade. The best germination on mineral soil occurred in the dry condition with moderate shade; that on hardwood leaves, on the other hand, occurred where the water table was high and under the same shading. Best results

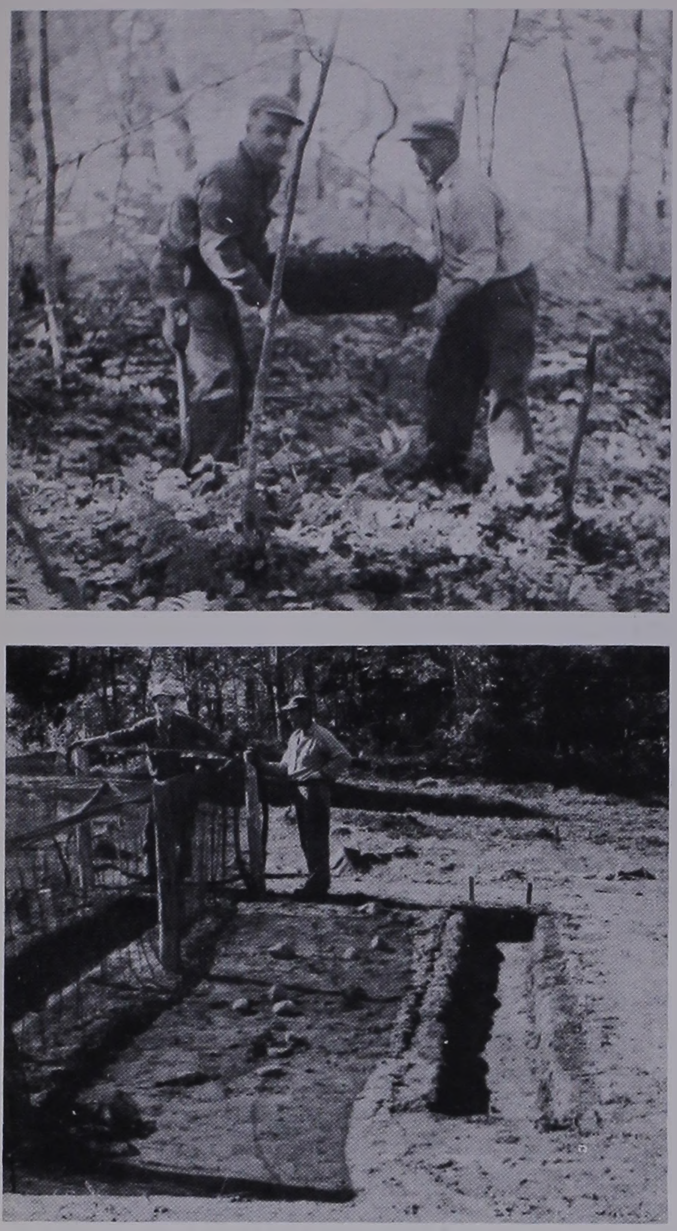

FIGURE 14. — How is the regeneration of yellow birch affected by seedbed, light, and moisture conditions? In a current study, blocks are lifted from the surface of the forest floor, transported to the seedbed study area, and placed in trenches. In the bottom photo, the trench on the right is being screened for shading.

on rotten logs and burned seedbeds were also obtained with moist conditions and shade.

Survival at the end of the growing season on most seedbeds was best under moderate shade with abundant moisture; on mineral soil, however, moisture conditions made little difference.

Height growth was much better on the organic seedbeds where the seedlings ran from 25 to 50 or more times taller than those on mineral soil; on the organic seedbeds, better growth was usually made under wet conditions, but moisture seemed to have little effect on mineral soil.

Marking Methods in Pole Stands

A test of various methods of preparing northern hardwood pole stands for the initial improvement and thinning cut was also completed. This was an appraisal of the silvicultural and cost aspects of pretreatment cruising techniques and methods of designating trees to be cut. Cost appraisal was based on the number of man-hours required for cruising and marking; the silvicultural evaluation was based on the improvement afforded the good growing stock in the stands treated.

The project was carried out at four locations in the Upper Peninsula of Michigan through the cooperation of both industrial and public foresters. Measurements were made by Station personnel, but marking was done by local foresters of considerable experience. All stands to be marked were cruised 100 percent to provide a true measure of total basal area, size distribution, and species composition.

Four marking methods, all aimed at reducing the stands to 80 square feet of basal area per acre, were tested as follows:

1. Individual tree selection.
2. Minimum diameter-limit designation.
3. Minimum diameter-limit designation with all crop trees marked to leave.
4. Maximum diameter-limit designation with all crop trees marked to leave.

The designation by means of a minimum-diameter limit involved the least time for preparation and marking. Selection marking took somewhat more time while diameter-limit designation plus crop-tree marking required the most time. In all methods, time was influenced by topography and the human element. Likewise the time required for selection marking was influenced by the number of trees marked.

As expected, selection marking left the stand in the best condition for future growth. Designation of the maximum diameter limit plus crop-tree marking gave satisfactory release to less than half of such trees, while 32 percent received too much release for best development of quality. Where trees to be cut were designated by a minimum diameter limit, over half of the crop trees were given no additional growing space.

If crop trees had not been marked in the minimum diameter method, it would have had little

effect on the end result, for only a few were larger than the limit set for removal. In contrast, a maximum diameter-limit cutting without reservation of crop trees would have removed over half of the best growing stock.

All factors considered, selection marking seems to have many advantages over other methods of designating trees for cutting in hardwood pole stands. Not only are the results more satisfactory in terms of placing crop trees in the best growing conditions, but shortcuts do not actually save much time when the necessary premarking procedures are taken into account.

Mixed Hardwoods Silviculture

Growth of Mixed Oak on Poor Sites

During the past year, existing information has been brought together on the growth and yield of the oak stands which occur on former pine sites in the central portions of the Lake States. The principal species are white oak (*Quercus alba* L.), black oak (Q. *velutina* Lam.), northern pine or jack oak (*Q ellipsoidalis* E. J. Hill), and northern red oak (*Q. rubra* L.). They are mostly of sprout origin and, being usually limby and defective, they produce low-grade timber (fig. 15).

The development of these poor-quality mixed oak stands was favored by logging the pine, which was composed mainly of red pine and scattered white pine with a minor oak component. Repeated fires following the logging destroyed the small merchantable pines and stimulated sprouting of the oaks. These denuded lands supporting clumps of oak sprouts were commonly typed as "scrub oak," and this term is still often used to describe the oak stands that have developed, even though many of them have now reached pulpwood and small sawtimber sizes.

The soils supporting these stands are generally deep, droughty sands with little textural differences in the B horizon. They belong mainly to the Podzols and Brown Podzolic soils in the Rubicon-Vilas-Grayling association and to the weakly developed Gray-Brown Podzolic soils of the Plainfield series.

Although such oak stands occupy nearly 2 million acres in the Lake States and are being increasingly cut for pulpwood, railroad ties, and pallet stock material, little research has been undertaken on their potential as a source of oak timber. This probably stems from the inferior quality of the timber produced. However, because of the large volume of pulpwood included in these stands, the question of oak management possibilities on these sites is still frequently raised by forest managers.

In a study made in 1926, growth of these so-called "scrub oak" lands was estimated to be only 1/5 to 1/3 cord per acre per year. The Station has established permanent plots in mixed oak on Grayling and Rubicon sands in connection with timber stand improvement studies. A recent analysis of the periodic growth of these plots shows that reasonably well-stocked mixed oak on Grayling and Rubicon sands, with basal area ranging from about 53 to 72 square feet per acre, makes a net periodic growth of only about 30 cubic feet or 0.4 cord per acre per year. This poor yield, as is true of oak on other low-grade sites, obtains in timber much poorer in quality than that produced on good oak sites.

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FIGURE 15. — The mixed oak stands on the sandy soils of northern Lower Michigan consist of small to medium-sized trees of slow growth and poor quality. John L. Arend measures diameter growth on a permanent plot.

Northern Conifers Silviculture

Measurement and Growth of Hazel

Among the many problems associated with the silviculture and management of northern conifers, one of the most important is brush. On upland sites, a chief offender is hazel (*Corylus* spp.), which causes serious interference with the establishment of both natural and artificial regeneration. Techniques to control this species are being developed and include the use of mechanical equipment, chemicals, and, more recently, prescribed burning. Along with these studies of control measures, it has also been necessary to work out methods of measuring or describing stands of brush so that the effects of control could be properly appraised.

Personnel of the Grand Rapids, Minn., field laboratory have recently developed a method of predicting the cubic-foot volume per acre of stands of hazel brush (fig. 16). The most useful of several prediction equations is:

$$V = .00481 \Sigma D^2H$$

where V is volume per acre in cubic feet including stems, branches, and bark; D is the diameter of individual stems measured 12 inches above ground; and H is height of individual stems.

Several interesting results came out of this study, among them that hazel stands can attain surprisingly high volumes per acre in a relatively short time. Temporary plots indicate per-acre volumes in pure brush fields of about 300 cubic feet per acre, with the oldest stems in the stand often less than 10 years old. This suggests growth rates in the pure stands in excess of 30 cubic feet per acre per year.

FIGURE 16. — Lee South *(right)* and Robert Buckman make measurements to determine the cubic-foot volume per acre of hazel. Some hazel stands (much denser than these) may contain as much as 300 cubic feet of wood per acre.

Since permanent rather than temporary plots give a more reliable appraisal of growth rates, data from the permanent plots in a prescribed burning study on the Cutfoot Experimental Forest will be of interest. These plots, described in Technical Note 620, have a red pine overstory averaging 120 square feet of basal area per acre; and as a result, the brush growth rates are lower than those of open-grown hazel. Nevertheless, the compartments spring-burned 3 years earlier now average 19.4 cubic feet of hazel per acre, 10.5 cubic feet of which grew during the third growing season. Compartments summer-burned 3 years earlier average 9.2 cubic feet per acre, 6.8 cubic feet of which grew in the third growing season. The unburned compartments, on the other hand, average about 35 cubic feet per acre and have been growing about 3.3 cubic feet per acre per year. It is interesting to speculate about what effect, if any, the rapid response of brush on the burned compartments may have had on the growth of the overstory red pine.

Black Spruce Growth Related to Peat Characteristics

Of the conifers naturally adapted to the extensive peatlands of the northern Lake States, black spruce is the most valuable. But the peat soils on which this tree is most abundant vary greatly in productivity. The best sites will produce yields as high as 60 cords per acre at maturity, but thousands of acres of "stagnant muskeg" are incapable of growing any pulpwood. Although there has been much speculation concerning the causes of this site variation, no definite information has been available until the Station completed its study of the soil-site relationships of peatlands.

This work was done in two important spruce-producing regions, the Glacial Lake Agassiz Peatlands (Lindford Area) and the small swamps of the Laurentian Shield in northeastern Minnesota (Section 29 Lake, Lake County). It shows conclusively that the poorer sites are associated with excessive accumulations of undecomposed sphagnum peat at the surface; in other words, as the sphagnum peat increases in depth, the site quality decreases (fig. 17).

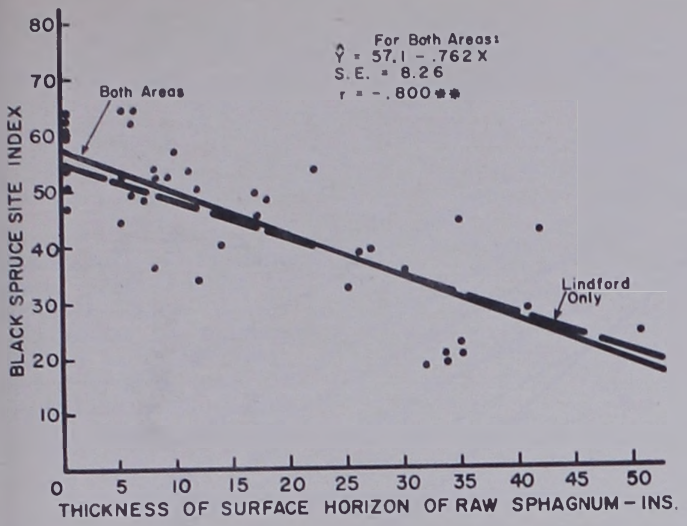

FIGURE 17. — Relation of black spruce site index (at 100 years) to thickness of the surface horizon of poorly decomposed sphagnum peat. Data from the Lindford and Section 29 Lake bogs, northern Minnesota.

In the Lake Agassiz region, there is much evidence of long-term site deterioration associated with *Sphagnum* accumulation. Even on the best sites there often is a thin horizon of raw sphagnum at the surface with well-decomposed woody peat only 5 to 10 inches below the fresh moss peat. The charcoal horizon often found at this level suggests that the present spruce forest is of post-fire origin and that the raw *Sphagnum* has accumulated only during the life of the present stand. In many areas of poor muskeg sites, raw *Sphagnum* peat overlies good forest peats that rest on the mineral soil substratum (fig. 18). This situation suggests that such poor areas were at one time better sites and have since been degraded.

Although acidity and total peat depth have been commonly believed to be useful site guides in black spruce, neither was closely related to site quality; occasionally acidities as low as pH 3.5 are found in the root zone (6-inch depth) on the best sites.

Plantation Management

Seed Production in Plantations

With more and more attention being given to the production of red pine and other conifer seeds in special plantations or other intensively treated areas, the results of a cone study carried on in Lower Michigan are of interest. Counts made in a twice-thinned 51-year-old red pine plantation show that seed production is influenced to a great extent by stand density. Both the percentage of trees bearing cones and the number of cones borne per tree were inversely proportional to the total basal area (fig. 19). At the lowest density in the study (85 square feet), practically all the trees bore some cones, while at the highest density only about one-third of the trees had cones, and these were much fewer in number. The comparison of viable seed production at the two extremes in density has still to be worked out.

Thinning and Storm Damage in Jack Pine

Since more and more conifer plantations are reaching the age when commercial thinnings are feasible, it is important to know how heavy such

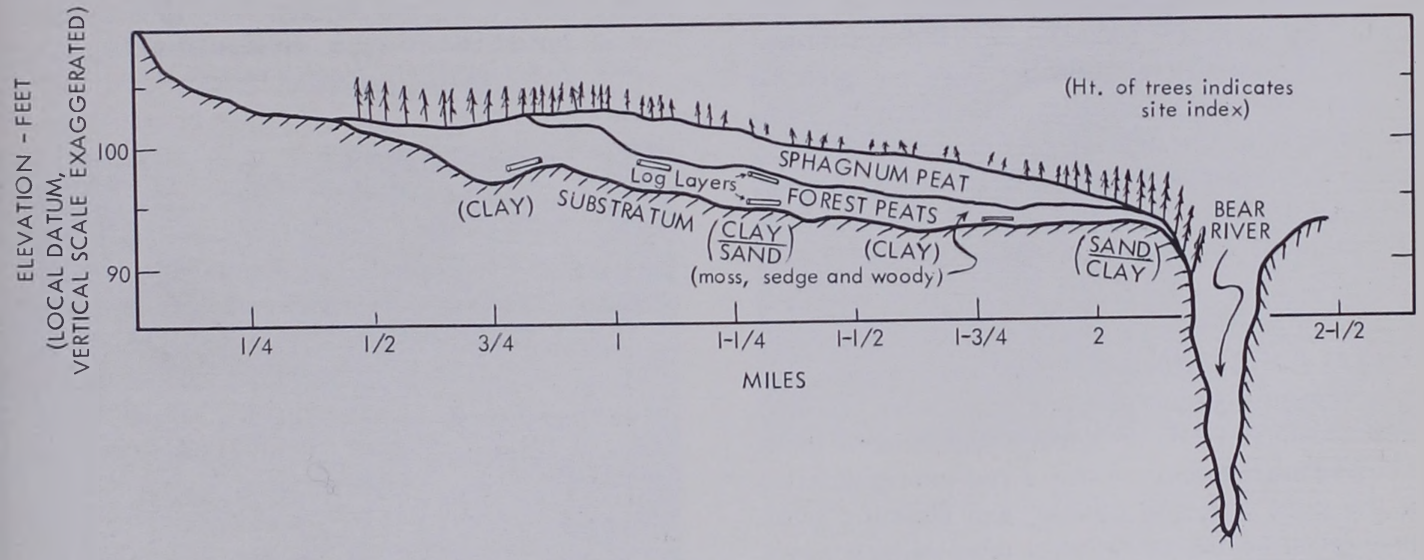

FIGURE 18. — Cross section of the Lindford peatland, showing peat stratigraphy and log layers in relation to spruce site quality (height of trees indicates relative site quality).

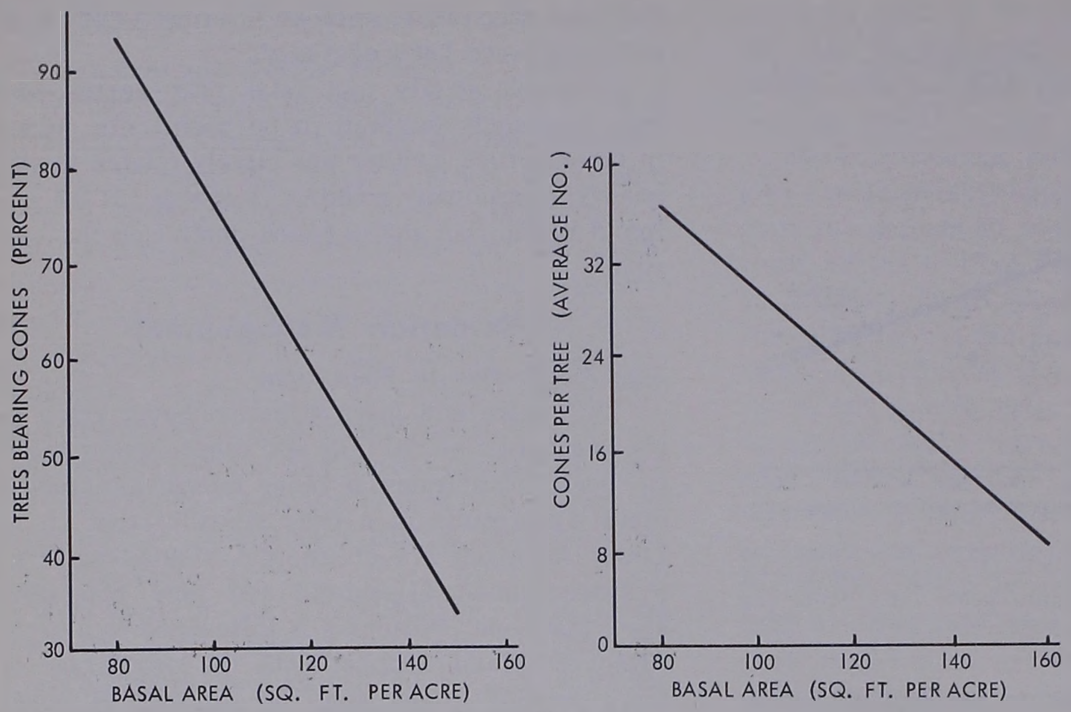

FIGURE 19. — Percentage of trees bearing cones *(left)* and average number of cones per tree *(right)* as related to basal area in a red pine plantation thinned to various densities.

thinnings can be without subsequent injury from climatic factors such as snow and wind. Additional evidence of the relation of snow damage to stand density is furnished by a recently thinned jack pine plantation on the Allegan State Forest. A heavy wet snow fell 1 year after the 24-year-old stand had been thinned to densities of 30 to 120 square feet of basal area per acre. The partial cuttings were made from below and by cutting every second or third row. The frequency of trees damaged decreased as the residual stand density increased, although there was not much difference between the 90- and 120-square-foot levels. Practically no damage occurred in the unthinned stands. The number of trees damaged per acre decreased from 145 trees in the 30-square-foot levels to 120 trees in the densest part of the stand. Row-thinned compartments had nearly twice as many trees damaged for comparable basal area densities as the plots thinned primarily from below.

The type of damage did not bear a consistent relationship to stand density. Broken stems accounted for about 60 percent of the damage (fig. 20). Rootsprung and uprooted trees were the next most frequent types of damage, but broken limbs occurred infrequently. Since a red pine plantation of the same age, site quality, and thinning treatment survived the storm with practically no damage, thinnings in this species are probably more resistant to snow damage than those in jack pine.

Healing of Pruning Scars in Red Pine

Some interesting data on the healing of pruning scars in planted red pine have also been obtained. Although rate of growth, wound size, and branch stub length all influenced the rate of wound healing, the rate of growth was the most important factor. The effects of wound size and the rate of growth on the time required for the scars to heal over and allow the production of clear wood are illustrated in figure 21. Pruning wounds of average width in this study required a layer of new wood approximately as thick as the width of the wound before clear wood was formed. The time required

FIGURE 20. — Severe snow damage to a 25-year-old jack pine plantation. Stem breakage was the most prevalent type of injury.

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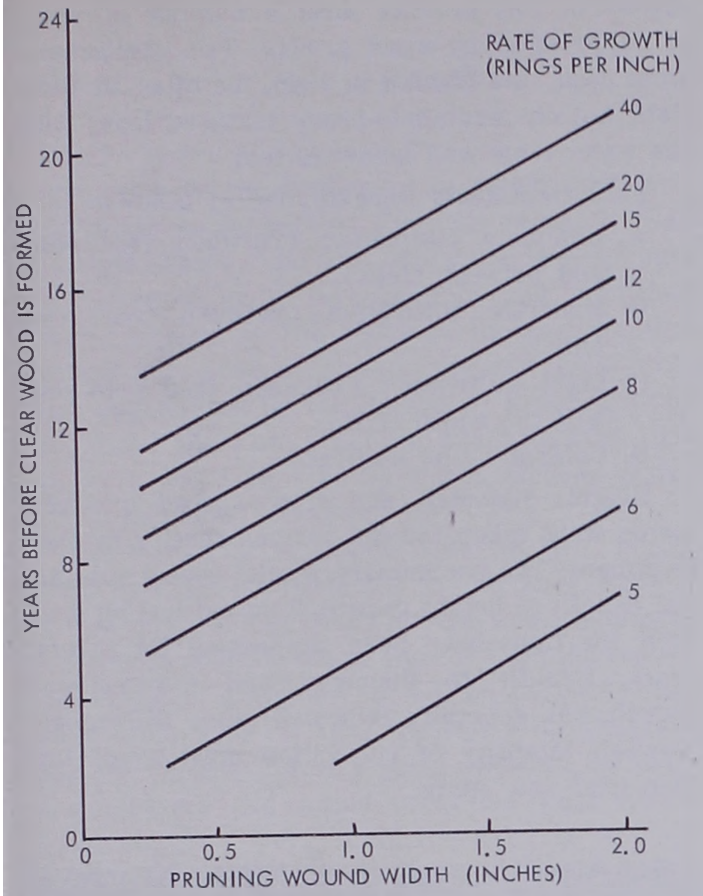

FIGURE 21. — Relationship between pruning wound width, rate of diameter growth, and the time before clear wood is formed in a red pine plantation.

to produce this layer depended, of course, on the diameter growth rate. It is important, therefore, to keep pruned trees growing at a rapid rate; and this can best be done by thinning the pruned plantations.

Shelterbelt Establishment and Management

The Station has been associated with the establishment and management of shelterbelts in the Northern Great Plains over much of its 40 years' history, having made its first plantings at the Denbigh Experimental Forest as long ago as 1931 (fig. 22). Although these required much hard work to bring them through the drought years of the 30's, they now form an island of thrifty young pine in the natural grassland of the Northern Plains.

Among the areas where work is being done on this project are weed control in nurseries and release of plantings from weeds by cultivation.

Weed Control in Nurseries

The control of weeds in Plains nurseries, especially in conifer seedbeds, constitutes a large item in stock production costs. A study was, therefore, begun in 1960 to determine the most effective application rates of the promising weed-killing chemical, methyl bromide, and to demonstrate its use under Plains conditions. This proved that the weeds (principal offenders, common purslane (*Portulaca oleracea*) and stinkgrass (*Eragrostis*

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FIGURE 22. — A ponderosa pine plantation on the Denbigh Experimental Forest. *Top*, shortly after planting in 1936; *bottom*, the same plantation 25 years later. This and similar plantings at Denbigh produced over 300 pounds of high-quality seed in 1962 which will be used locally to grow planting stock.

cilianensis)) in newly sown pine seedbeds could be effectively controlled by the application of one-half pound or more of methyl bromide per 100 square feet of bed (fig. 23).

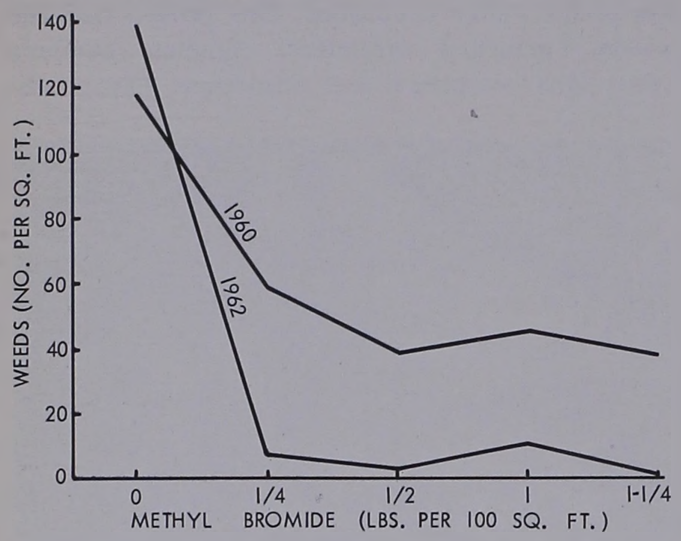

FIGURE 23. — Effect of fumigation with methyl bromide on weed population in nursery seedbeds.

Treated beds had significantly higher densities of seedlings than the untreated at all rates of application due in part to reduction from damping-off and in part to the reduction in weeds. Beds fumigated at the rate of ½ pound and up produced seedlings that were larger in top length, caliper, and total green weight and this in spite of the greater seedbed densities.

Release of Plantings by Cultivation

Grasses and other weed growth, because of the competition they furnish for soil moisture and possibly nutrients, are a serious threat to the growth and survival of shelterbelt plantings in the Northern Great Plains (fig. 24). Where this competition has been ignored, many plantings have become suppressed and have suffered early mortality. Others have held on, making a minimum of growth.

Since cultivation has proved an effective aid in the establishment of shelterbelts in this region, a study was established in 1960 to determine the effects of this practice after a number of years of suppression by weed growth. Two shelterbelts were used, one planted in 1946, the other in 1949. Both are on medium-to-heavy textured loam with the water table well below 10 feet.

Four treatments were applied as follows:

A. Complete cultivation (between tree rows and between trees).
B. Moderate cultivation (between tree rows only).
C. Light cultivation (between tree rows but half the width of *B*).
D. Control — no cultivation.

Height, diameter, and crown-spread measurements were taken for the various species in each treatment. The preliminary results reveal substantial benefit to height growth from cultivation even after the trees have been suppressed for several years. Benefit to diameter and crown-spread growth was generally indicated, also. Differences between intensity of cultivation must await further trial and study.

FIGURE 24. — Paul Slabaugh measures soil moisture under undisturbed bromegrass sod.

Interest in the economics of forest land uses and products guided the Station's research from the start. Throughout the 1920's the Director and staff pursued many investigations and published several reports on the status of the region's timberland in relation to the economic and social problems engendered by the demise of the virgin forests. Until the Forest Survey was begun in 1933 the work was hampered by a lack of basic statistics on the forest resource.

Publication of Economic Note No. 10, "Forest Areas and Timber Volumes in the Lake States," by Cunningham and Moser in 1938 was a landmark in resource analysis. These figures from the region-wide timber inventory, based on 120,000 plots taken from 1933 to 1937, provided for the first time the reliable forest statistics needed for planning research and action programs. Lake States forest statistics were summarized again in 1945 as part of the nationwide Reappraisal, and again in 1953 for the Timber Resource Review. Currently a fourth summary is being prepared, based on surveys completed since 1953. Reports on inventories made in the 30 years of the Forest Survey now fill a wide shelf, showing in detail the changes taking place in resources and industries.

Commodity production reports and timber cut estimates are other Forest Survey activities. Of major interest is the pulpwood production series, dating from World War II and including in recent years estimates of pulpwood cut by county of origin. Reports on lumber and other products are issued from time to time.

During 1962, demand for forest resource information reached a new high. The Area Redevelopment Program and allied activities stimulated an increasing number of requests for up-to-date estimates of timber volume, growth, and allowable cut. In some areas the most recent statistics are fairly current and are adequate for planning; in other areas they are obsolete. Up-dating by bookkeeping methods is rarely satisfactory. Despite the obvious need for new surveys in northern Michigan and elsewhere, the Station has avoided attempting to adjust the figures for parts of States. Instead we have held to our State-by-State schedule, covering the territory as rapidly as is consistent with doing a thorough job with available funds.

Survey Schedule Explained

The Lake States Station is charged with collecting timber resource information in 13 States. In 1959, a schedule (table 1 and fig. 25) to provide for inventorying 10 States in a 10-year period was prepared and correlated with National Forest management plan inventories. This provided a third survey of Minnesota, Wisconsin, and Michigan, and a second survey of the Northern Plains and Central States. During the integration period a longer cycle was required for all States. Iowa, Nebraska, and North Dakota were left for the early part of the next cycle when they may be inventoried simultaneously with Missouri and Minnesota. Beginning in 1969, all States should be surveyed each decade, providing adequate funds are available to maintain such a schedule.

Four years of the present decade have passed. Fieldwork has been completed in Missouri, Minnesota, and Illinois, and is under way in Kentucky. Because new measurements and extra computations have been added to the work, the survey is about three months behind schedule.

The Station spends only sufficient Forest Survey funds in each State to meet national standards

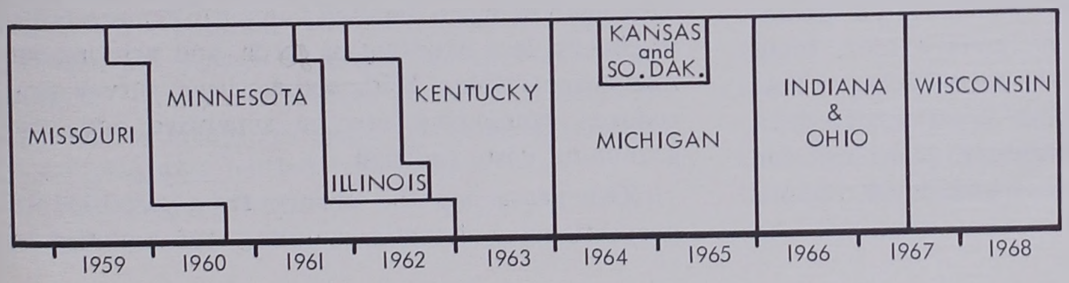

FIGURE 25. — Schedule for inventorying timber resource in 10 States.

TABLE 1. — *The Forest Survey schedule*

State	Land area	Commercial forest area	Most recent survey statistics	Resurvey midpoint	Time required to reinventory
	Million acres	*Million acres*	*Year*	*Year*	*Years*
Missouri	44.3	15.07	1947	1959	1.5
Minnesota	51.2	18.10	1946-53	1961	1.5
Illinois	35.8	3.94	1948	1962	.6
Kentucky	25.2	11.45	1948-51	1963	1.4
Michigan	36.5	19.12	1946-56	1965	1.6
South Dakota (east)	41.9	.50	1935	1965	.2
Kansas	52.5	1.66	1936	1965	.2
Indiana	23.2	4.04	1950	1966	.7
Ohio	26.2	5.40	1952	1967	.8
Wisconsin	35.0	15.40	1950-58	1968	1.5
Iowa	35.9	2.60	1954	1969	—
North Dakota	44.8	.45	1954	1971	—
Nebraska	49.1	1.05	1955	1971	—
Total	501.6	98.78	--	—	10.0

of accuracy. This provides standard forest statistics for the State and two or more major subdivisions. If additional information or county statistics are desired and can be financed by others, the Station will cooperate toward those ends.

Forest Survey data for Missouri have been computed. Two district reports (Eastern Ozarks and Prairie Region) have been written and one published. Work is progressing on the State report. The Minnesota inventory work was delayed so that new aerial photography might be used and more accurate results obtained for the northeastern counties. With new photos available the Superior National Forest, the Office of Iron Range Resources and Rehabilitation, and the Station put on a crash program to complete the State in 1962. Computing is well along and will be finished in 1963. Statistics for Koochiching County were computed to test new data processing procedure and will be published early in 1963. Also to be done in 1963 is the computing for the Illinois survey; fieldwork for that State was completed in one year.

The State of Kentucky provided $120,000 to intensify the Forest Survey there. Aerial photointerpretation was begun in January 1962, fieldwork in July. Planning for the next Michigan Forest Survey is under way. While 2 years have been set up for the Michigan inventory, plans call for a few men to work in Kansas and South Dakota during this period.

Many Improvements in Survey Methods

The revolution in Forest Survey methods is continuing. Two years ago the use of 13 points on a 1-acre plot for classifying area (stand) conditions was reported. Now 10 subpoints on the sample acre are used to measure volume as well as growing conditions. The trend is toward making a number of simple, objective classifications at each point. These may be used by automatic data processing machines to arrive at the area and tree clasifications desired. For example, observations are made of surface defect, internal defect, sweep and crook, relative bole length, tree vigor, and tree damage, from which tree class is determined. This provides a much more consistent and accurate classification than can be obtained by a broad subjective judgment. During the past year the Station took part in three meetings of the survey leaders in the Eastern United States. Important progress was made toward standardization of techniques, methods, and definitions.

Two years ago we reported increased use of automatic data processing machines. Since then a shift has been made to much faster and more versatile machines with larger memory systems. This enables more detailed computing, more built-in checks, less handling of cards, and printing-out many final tables. With standardized survey procedures, computing can be repetitive and programming costs reduced.

Two years ago the change from stratified to proportional systematic sampling was reported as

was the change from fixed-area to angle-gauge plots. Since then Multiple Random Starts have been used in the Illinois and Kentucky sampling designs. A cooperative study has been arranged with the University of Minnesota to analyze the results of the Illinois survey and determine precisely the benefits from this design.

Status of Plantations Analyzed

As the second Forest Survey of Michigan drew to a close, several questions arose about forest plantations:

1. How many acres of plantations were there?
2. How were they developing?
3. What yields could be expected during the next 10 years?

Plantations weren't handled as a separate classification in the Forest Survey because of the light sample and relatively small areas involved. Information on yields from improvement cutting in immature stands was not available. No satisfactory procedure for calculating allowable cut from plantations had been devised.

A special study to provide this information was made in the northern half of the Lower Peninsula. A sample was drawn from nursery records of trees shipped since about 1900. Shipments were followed to the field and plots were established in the plantations. The study showed that some 660,000 acres had been planted and about 517,000 acres were adequately established as plantations. Of these, 400 acres had reached sawtimber size, 27,000 acres were medium- and well-stocked poletimber, 35,000 were poorly stocked poletimber, 338,500 acres were medium- and well-stocked saplings and seedlings, and 116,000 were poorly stocked saplings and seedlings. Thirty-nine percent of the established plantations were found to have a competing native tree overstory.

Considerable evidence was obtained on how trees in plantations grew. Most striking was the retarding effect of an overstory on growth of timber volumes (fig. 26). Nearly one-fifth of the established plantations had suffered some serious pest damage. About 8 percent of all established plantings showed evidence of having received some kind of stand treatment, and some 28 percent of the plantings needed treatment.

Estimating allowable cut is especially difficult in plantations. A fast-growing stand may not have sufficient volume to warrant a commercial cut at the time of inventory, but may yield a 10-cord cut before the next 10 years are over. Many trees reach merchantable size at about the same time. The authors prescribe that the allowable cut include the cut on the thinnable stands at the time of measurement plus improvement cuts on stands expected to move into merchantable size during the next 10 years.

For more details the reader is referred to Station Paper No. 102.

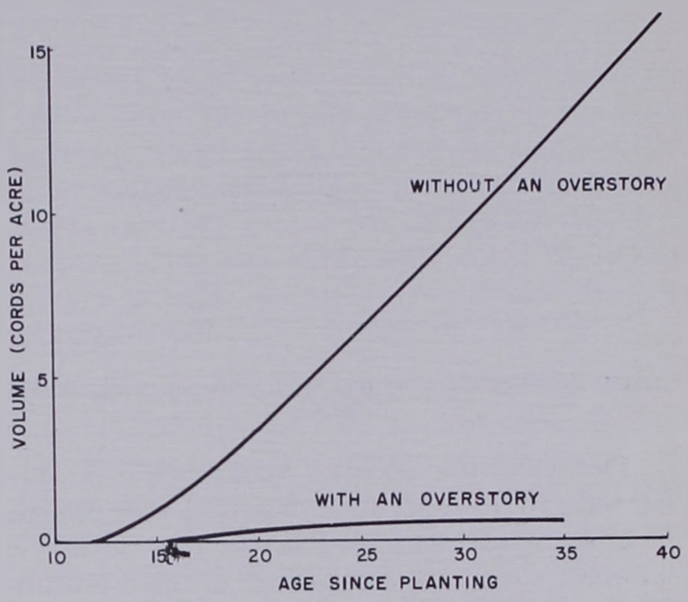

FIGURE 26. — Volume of red pine in plantations without a native overstory and with a native overstory of 3 cords or more per acre.

Several Timber Product Studies Completed

Following a schedule geared to furnish timber cut data for States where forest inventories are underway, the Station completed a number of timber product surveys during 1961 and 1962. One of these was the annual regional pulpwood survey made with the assistance of the Michigan Department of Conservation. Production surveys of all forest commodities were made in Minnesota and Illinois. Results, when compared to those of previous years, point up some interesting changes in cutting trends for some timber products and species.

Lake States Pulpwood Survey

The Lake States harvest of pulpwood in 1961 amounted to 3,152,000 cords, 6 percent less than that of the previous year which was an all-time high. Although 1961 production declined slightly,

the cut during the past 10-year period has moved strongly upward (fig. 27). The gains in both Michigan and Wisconsin have been pronounced while the cut in Minnesota has remained almost static.

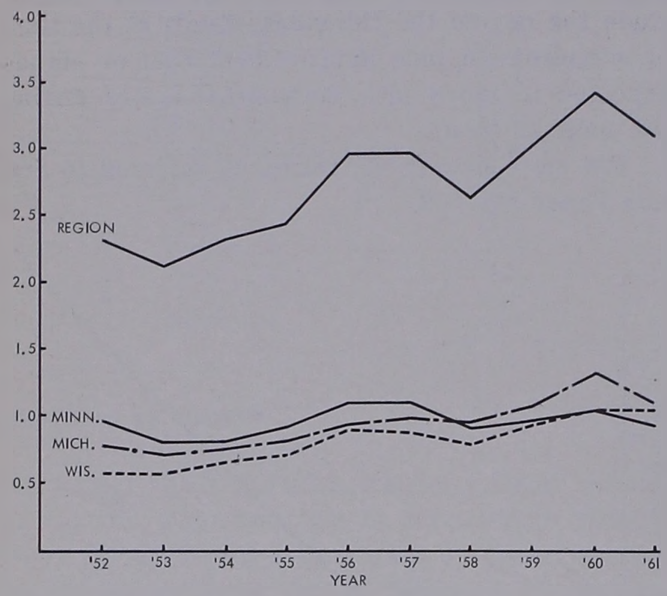

FIGURE 27. — Pulpwood production trends, Lake States, 1952-61.

Increasing use of Lake States pulpwood during the past 10-year period coincided with changes in procurement areas and in the relative use of different species. A comparison of 1961 procurement with that of other years for which district totals are available shows sizable rises in pulpwood cut in the northwest district of Wisconsin, the north half of the Lower Peninsula of Michigan, and northeastern Minnesota (table 2). The increase in Lower Michigan has been most remarkable. By species, the miscellaneous dense hardwoods have increased the most, posting a large gain in 1961 over the amount produced in 1952 (table 3). Other species that registered sizable gains were white birch, aspen, pine, and tamarack. The use of hemlock, balsam fir, and spruce has declined in spite of a rising pulpwood market.

Minnesota Lumber Production

A canvass of sawmills in northern counties and a sampling of sawmills in the southern half of Minnesota were completed in 1961, through the efforts of many Minnesota forestry agencies. Minnesota sawmills produced about 161 million board feet of lumber in 1960, 16 percent less than the 191 million board feet produced in 1953. Most of the decrease occurred in the north central and northeastern counties. Permanent shutdowns of several medium-to-large sawmills, coupled with a weak market for jack pine and aspen lumber, were the factors largely responsible. Of the 112 million board feet of lumber produced in the northern counties, only 60 percent found its way into commercial markets.

Processing logs into lumber by Minnesota sawmills produced approximately 150,000 cords equivalent of slabwood, edgings, sawdust, and shavings

TABLE 2. — *Pulpwood production trends by districts for 1961 and previous survey, Lake States*

State and district	Annual cut (thousand cords)		Percentage change since previous survey
	Previous survey[1]	1961	
Minnesota			
Northeast	375	461	+ 23
Central Pine	297	290	— 2
Rainy River	228	195	— 14
Hardwood and Prairie	37	22	— 40
Wisconsin			
Northeast	402	458	+ 14
Northwest	325	403	+ 24
Central	227	203	— 11
Southwest and Southeast	6	14	+ 133
Michigan			
E ½ Upper Peninsula	191	249	+ 30
W ½ Upper Peninsula	360	375	+ 4
N ½ Lower Peninsula	219	450	+ 105
S ½ Lower Peninsula	27	32	+ 19

[1] *Pulpwood production on a district rather than a State basis was first obtained in Minnesota in 1952, Michigan 1954, Wisconsin 1956.*

TABLE 3. — *Pulpwood production trends by species, Lake States (1952-1961)*

Species	Percent-change 1961 vs. 1952	10-year range in output			
		Low		High	
		Year	M cords	Year	M cords
Aspen	+ 78	1952	821	1960	1,601
Balsam fir	— 27	1953	248	1952	391
Birch, white	+ 103	1953	18	1961	51
Hemlock	— 52	1959	88	1952	191
Pine	+ 49	1952	347	1959	623
Spruce	— 20	1953	322	1957	491
Tamarack	+ 32	1953	8	1960	29
Misc. hardwoods	+ 727	1952	40	1961	330
All species	+ 38	1953	2,091	1960	3,337

in 1960. More than one-half was slabs and edgings. According to mill operators, over 60 percent of this material was consumed as domestic and industrial fuel and charcoal wood.

Forest Product Utilization Factors for Minnesota

To determine the volume of timber removed from Minnesota forests in 1960, two jobs were done. The first was a canvass of producers to determine the quantities of rough forest products harvested, and the second was a logging study to come up with factors for estimating the volume of merchantable timber cut per unit of output of various timber products. For this purpose the Station, together with the Office of Iron Range Resources and Rehabilitation, measured and studied 800 felled trees at 75 widely scattered logging operations.

Cutting for different products removes varying proportions of sawtimber and poletimber trees, cull trees, dead trees, and limbwood. Fuelwood cutting takes the largest proportion of low-grade material, veneer logs and piling the smallest. The study further shows that the volume of logging residue left per unit of output was the largest in cooperage log and hardwood lumber log operations, and was zero in fuelwood and charcoal cuttings.

Comparing the findings of the current Minnesota utilization study with the one made 10 years ago, there has been a significant increase in the use of sawtimber-sized trees, especially for such products as pulpwood and box bolts. Ten years ago more than half of the timber harvest came from trees of less than sawtimber size; today the reverse is true. Since 1952 large numbers of poletimber-size trees have grown into the small sawtimber-size class; hence the increase in the use of the larger trees.

PRODUCTION ECONOMICS AND MARKETING

Forest products marketing research has evolved in response to changing times. Originally an emergency measure designed to increase the production of wood products needed for war, it now seeks to promote the harvest of surplus timber to aid forest management and local economies. The effort includes studies of all the factors affecting market opportunities, particularly the long-range trend of available timber supplies. With the new direction of marketing research have come analytical studies of the costs and returns of producing quality timber under management. In the Lake States the emphasis is on the economics of management on relatively large properties, dictated by the high proportion of forest land in public and industrial ownership.

Along with changes in timber stand characteristics have come changes in ownership patterns and of owners' reasons for holding forest land. Believing that these changes will affect future timber production and forest recreation opportunities, the Station has made several studies of the characteristics of small owners. A comprehensive report on the forest owners of Michigan will appear next year.

Details on our progress on some of the major economics problems appear on the following pages.

Red Pine Profitability Analyzed

Research at the Lake States Station on the economics of timber growing is exploring the financial consequences of thinning even-aged red pine stands to various basal area densities over a range of site and marketing conditions.

As a byproduct of this work, a Fortran electronic data-processing program was developed to evaluate timber production alternatives. The program computes present discounted values of future net returns from each alternative timber production schedule for a range of specified rotation ages, discount rates, and stand establishment costs. These results are printed-out in a table. The machine simultaneously picks out the maximum present net value for each interest rate and stand establishment cost and prints these values and the associated rotation ages in a summary table. These two sets of tables provide the basic information for evaluating alternative timber production schedules directly in terms of present values. The financial yield or rate of return for each alternative can be determined by a simple graphical procedure.

This machine program has made it possible to evaluate a large number of timber production alternatives in even-aged red pine stands, including financial rotation ages, number of trees and basal area density per acre, site index, stand establishment costs, and markets. Although the analysis has not yet been completed, several conclusions are evident.

In periodically thinned red pine stands, rotation ages can vary considerably from the rotation age maximizing financial rate of return and still have little effect on the average rate of return on the total timber stand investment (fig. 28). This conclusion holds over a wide range of sites, stand densities, stand establishment costs, and market conditions. It is also evident that the rotation age maximizing the rate of financial return is longest on the most heavily thinned stands, and shortest on the most lightly thinned stands.

For almost all conditions examined in this analysis, stands with low numbers of trees (not more than 800 trees per acre) and managed at low basal area densities (thinned every 10 years to 90 square feet of basal area per acre) have shown the highest financial rate of return (see figure 28 for an example on one site for 800 trees per acre). However, stands managed at such low densities cannot be carried as long as stands managed at higher densities.

Site can greatly affect the financial rate of return earned in timber production. For example, investing $50 per acre in stand establishment on site-index-40 land may give only a 2½-percent

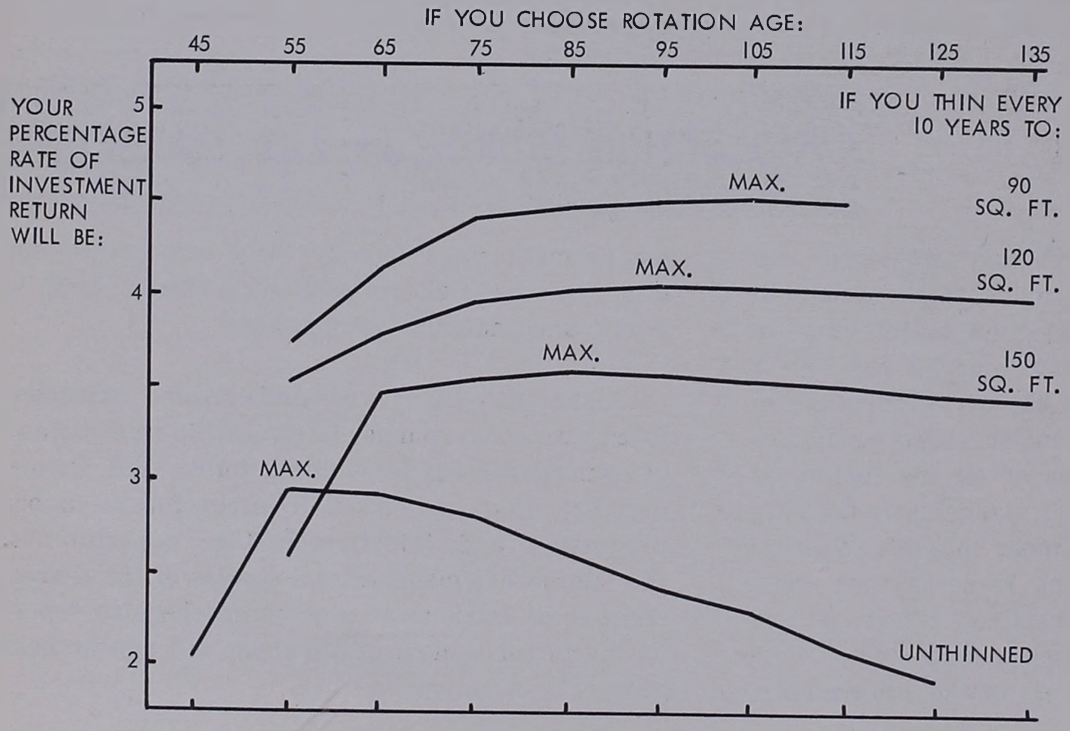

FIGURE 28. — Rotation ages can be changed at little cost for red pine stands thinned periodically. "Max." indicates the point at which the rate of return is maximizing. (Assumes higher stumpage prices for larger diameter trees, $40 per acre stand establishment cost, $0.50 per acre annual management expenses, and land cost of $5 per acre. Site index 60: 800 trees and 137 square feet of basal area per acre at age 25.)

rate of return, whereas the same investment on site-index-70 land may give almost 5½ percent (fig. 29). The importance of site is also reflected in the amount that can be invested in stand establishment and still provide a given rate of investment return. Cheap land with low stand establishment costs is not necessarily a good investment if the land is of low productivity.

Michigan Forest Ownership Reports

Two publications released by the Station during the past year describe the small private forest ownership situation in selected areas of Michigan. One report, Station Paper 95, concerns the Upper Peninsula, while Station Paper 103 deals with the small ownerships of southern Lower Michigan. Both of these studies bring out the fact that only a small minority of these forest landowners have

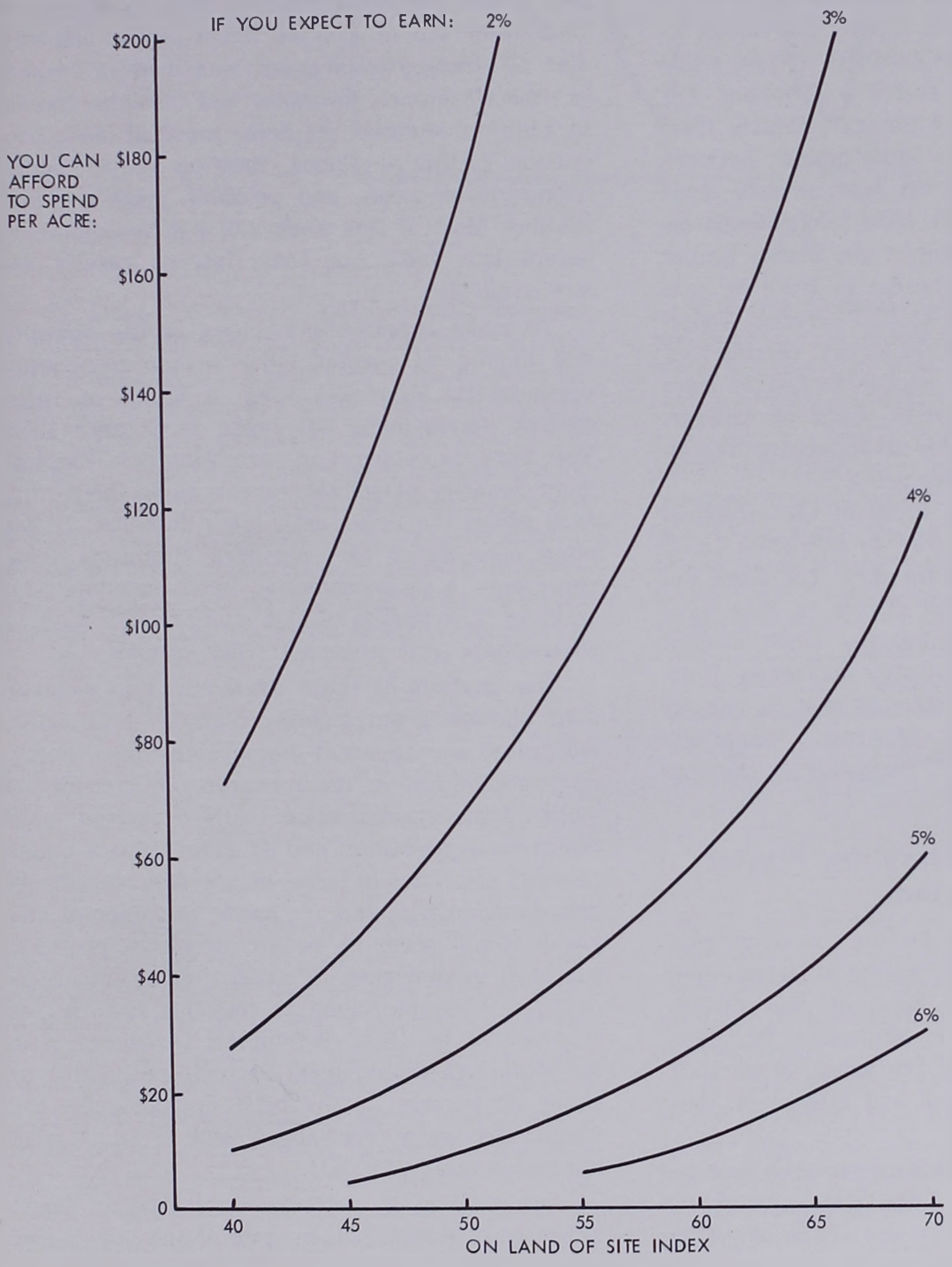

FIGURE 29. — The forest manager can afford to spend more to establish a timber stand on better quality land. (Assumes a stand of 800 trees per acre at age 25, thinned to 90 square feet of basal area per acre every 10 years, higher stumpage prices for larger diameter trees, $0.50 per acre annual management expenses, and $5 per acre land cost.)

an active interest in the timber-producing capacity of their forest land. A variety of reasons was given for holding forest land — recreation, residence, liquidation of growing stock, speculation — but only a few owners claimed "timber production" as an objective of ownership.

Another report, nearing completion, will summarize what is known about Michigan's small private forest landowners and comment on the kind and amount of forest management being practiced on large private and public forest lands. Recent trends in harvesting show that the latter class of forest ownership is rapidly increasing its share of Michigan's timber products output, while the cut from the private sector is dropping. For example, the output of all timber products from Michigan's public forests quadrupled between 1950 and 1960, while the cut from private lands dropped by 32 percent. In 1950 public lands accounted for only 4.8 percent of the State's timber cut from growing stock, whereas in 1960 the public forests' share had risen to 22.5 percent. Apparently forest management practices carried out on Michigan's public lands during the last 30 years are commencing to bear fruit. Lack of management on most private lands undoubtedly has an adverse influence on timber sales.

Future plans include a study of the effectiveness of various methods used to influence small private owners to practice forestry. The work described above indicates that efforts to date have been ineffective in informing the small owners about the availability of forestry assistance. However, these same studies indicate that in certain areas a strategic minority of owners would respond to increased publicity on available forestry assistance.

Forest Products Marketing Project Relocated

To better carry out the Station's research program in forest products marketing a Station field office was established in June on the Duluth campus of the University of Minnesota. Dr. Dean N. Quinney is in charge of the work. Other staff members are James E. Blyth and Eugene M. Carpenter.

From this location marketing research will be carried on throughout the Lake States. Its objective is to make more efficient use of the available timber resources by providing to existing or new industries data on timber availability, production costs, and potential markets. The end result would be to encourage expanded economic opportunities in the rural forested areas of the Lake States.

The staff initially is working on a detailed analysis of the timber resource, production costs, and marketing factors that affect opportunities for manufacturing and marketing wood products in northeastern Minnesota. This study will concentrate on an intensive analysis of the new Minnesota Forest Survey statistics (to be available in 1963) and should provide much better planning data to existing wood-using industries in respect to timber volumes, locations, and resource trends. In addition, analyses are being made of other production factors — labor, location requirements, transportation costs, and probable market opportunities. Most of this work will not be completed before late 1963, but some interim results are now available.

To make a better assessment of the quantity and quality of surplus labor in the five-county northeastern Minnesota area, a study of those seeking employment was made in October 1962. This work, in cooperation with Minnesota Employment Security personnel, reveals some interesting facts about the under-used labor resource. It has often been stated that northern Minnesota labor represents a high potential in background and training. The results of this study would seem to substantiate and document this opinion.

The analysis of those unemployed in October 1962 showed a surprisingly high level of skills, education, and apparent employable status. Forty-one percent fell in the management, clerical, or skilled labor classes; more than 40 percent were high school graduates; and 42 percent were under 35 years old. Thus in terms of previous work background, education, and age levels, this unemployed group would seem to be an attractive pool for potential employment in wood-using or other industries. Unemployment in the five counties as represented by those individuals registered with the Minnesota Employment Security (estimated as about 80 percent of the total unemployed) has ranged seasonally from about 4,500 to 11,000 over the last 4 years (fig. 30).

An analysis of overseas commerce at Great Lakes ports shows that, in spite of the opening of

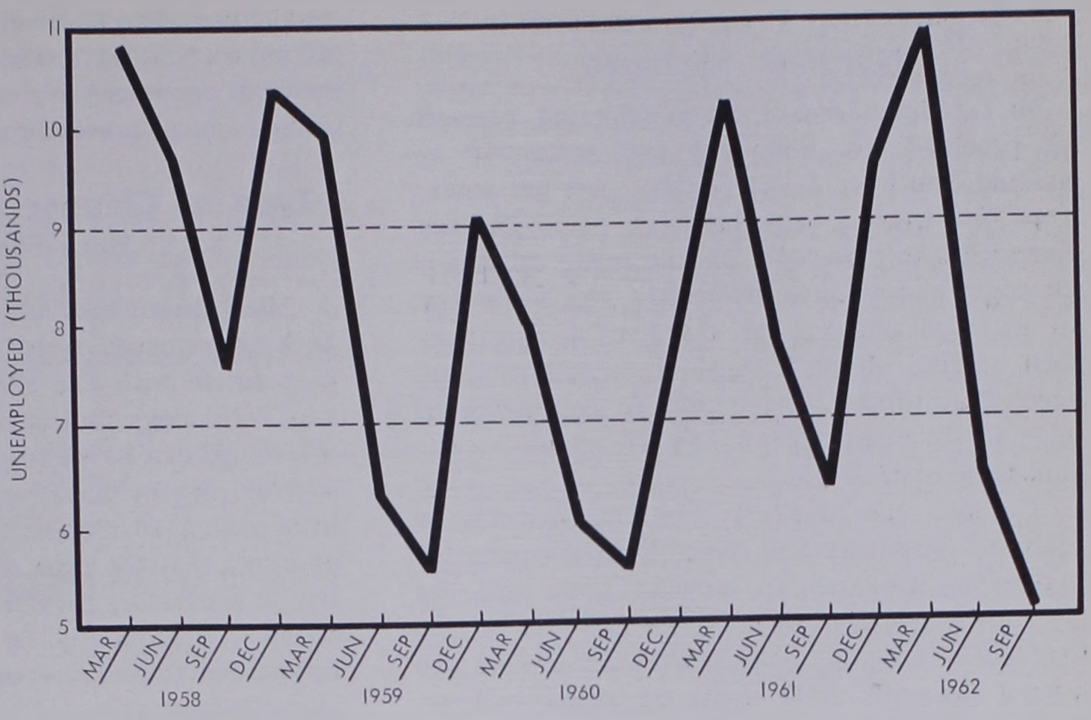

FIGURE 30. — Quarterly unemployment trends in St. Louis County (including Duluth), 1958-62. According to the 1960 Census of Population, St. Louis County contains 79 percent of the five-county labor force.

the St. Lawrence Seaway and the establishment of Duluth as an overseas shipping and receiving port, Minnesota has shared very little in overseas wood and wood products trade. With the possibility of expanded construction and consumer goods markets in presently underdeveloped portions of the world, overseas shipping of wood and wood products from Minnesota could help to expand present marketing horizons. Undoubtedly there are many complex factors affecting these overseas markets (including the effect of trade associations such as the Common Market), but research into opportunities for overseas marketing of wood and wood products shipped from Lake States ports certainly seems justified.

These few results indicate some of the phases under investigation in this current market development research project. Other phases, including the resource and market analysis, should be completed some time next summer and published summaries will be released as soon as they can be made available.

FOREST UTILIZATION AND ENGINEERING

Forty years ago, cutover forest lands called for a thorough understanding of how to get second-growth forests started, and we conducted research on planting, natural regeneration, and protection. As the young forests grew, we learned how to improve their quality and growth and how to protect them from fire and pests. Some of these second-growth stands are now being harvested and others will soon reach that stage. To keep these young forests economically competitive with those of other regions, greater emphasis must be placed on how to harvest trees at the lowest possible cost, how to do this without damaging the residual stand, how to select trees most suitable for a given product, and how to encourage greater natural regeneration.

In recognition of these problems, the Station in the late fifties established research programs in forest utilization and in forest engineering. In the following pages is a brief summary of what we are starting in forest engineering and what we have underway now in forest utilization.

Engineering Project Located in Northern Michigan

In farming, agricultural engineering research has provided new know-how and equipment for planting, cultivating, harvesting, and processing crops. In forestry, there has been no similar concentrated effort. Recognizing the many equipment development problems in forestry, the Station set up an engineering research project at Houghton, Mich., in 1961. Rulon B. Gardner, an engineer, was selected as project leader, and he is assisted by John R. Erickson, a mechanical engineer who joined the staff in 1962.

To date, the emphasis has largely been on analyzing problems and possible approaches for engineering research. In addition, some time has been spent in studying the type of facilities needed for such a program. Offices for the project are located presently in a small temporary building at Michigan College of Science and Technology. A Forest Engineering Laboratory on the campus at this location is under consideration. Such a facility would permit research on the design and development of harvesting systems, and of models for improved forestry equipment. It would also serve as a focal point for other research and testing of equipment dealing with regeneration, planting, and related silvicultural practices. Northern Michigan is a particularly favorable location because of numerous wood-using industries. In addition, the surrounding region is virtually an outdoor laboratory and diversified field testing area encompassing many variations in topography, soils, and forest types.

A major problem under study is the present system for harvesting roundwood. Improved methods for both harvesting and transporting such material might encourage additional wood consumption and industrial development. Chipping of roundwood at its source, for example, with especially designed techniques and equipment is beginning to offer promise for improved forestry and for lowering costs for moving and using pulpwood. Through improved design for chipping there may be opportunities for producing a more desirable chip, as well as substantially lowering power requirements for processing.

Another subject receiving attention is the vast acreage in the Lake States of low-quality aspen stands which need to be converted to a more productive forest. Involved is the development of an economical method and equipment for removing aspen and for utilizing the merchantable component of present stands.

Type of Chipper Affects Amount of Bark-Free Chips

Most known uses of chipped wood require that bark be removed from wood. A recent study in cooperation with The Michigan College of Science and Technology indicated that sugar maple rough woodchips can be successfully stored outdoors for several months but that the bark loosens very little within 18 months. During this study it was observed that the type of chipper used was effective in separating bark from wood in the chipping action. Consequently, a cooperative study was established to measure the effect of several basically different types of chippers on sticks of different size, condition of wood, and season of chipping. Quantitative data for the dormant-season chipping of fresh wood show that both chipper type and size of stick may be factors in bark adherence to wood in the chipping action. The percentages by weight of chips that had bark adhering to them after the sticks had been through the chipper are shown below.

	Diameter of Stick (inches)			
Chipper type:	2	4	6	8
Straight knife disk, gravity feed	11.8	2.1	0.5	1.3
Helicoid knife disk, gravity feed	9.3	2.0	1.2	1.0
Straight knife disk, horizontal feed	3.7	.5	.2	.2

The straight knife disk, horizontal feed chipper produces a higher percentage of bark-free chips in all diameter classes of wood.

A second phase of this study, which includes an investigation of means of segregating bark particles from the woodchips, is being carried on concurrently with the raw material available from the chip separation study.

Tree Quality in Hardwoods Indicated by Stem Characteristics

How to discern from the outer appearance of a tree whether it should be favored over its neighbors is a perennial problem in forestry. Many trees

have been selected as suitable for high-value lumber or poles and nursed along to maturity only to be seriously defective when cut and sawed. Basic to a better understanding of this subject is having answers to such questions as:

What stem characteristics mean in terms of wood quality for each of several end products; i.e., lumber, poles, pulpwood, ties.

How each of these characteristics affect the wood yield.

How the size and appearance of outer defects are correlated with wood loss due to rot and stain and other defects.

What all these relationships add up to for individual tree species.

By 1961 new techniques for studying and analyzing these problems had been developed. After a series of test runs it was decided to express the many indicative tree characteristics quantitatively, and to determine the effect of each of the large number of possible combinations on tree quality. When this had been worked out, the most important stem characteristics affecting tree grade could be selected and estimation equations developed.

To use these equations, it is necessary to record the required stem characteristics and tree measurements and forward them to a data processing center. There an electronic computer will apply the equations, extend current prices for the desired products, and express answers in terms of dollar value.

In the past 2 years, considerable progress has been made toward developing the estimation equations. Working with the data from two 45-tree sugar maple samples, we have selected a number of tree stem characteristics for analysis. These include diameter breast high, merchantable stem length, total tree height, stem taper, number of exterior defect indicators and the average vertical distance between them, diameter growth rate, tree age, and crook and sweep.

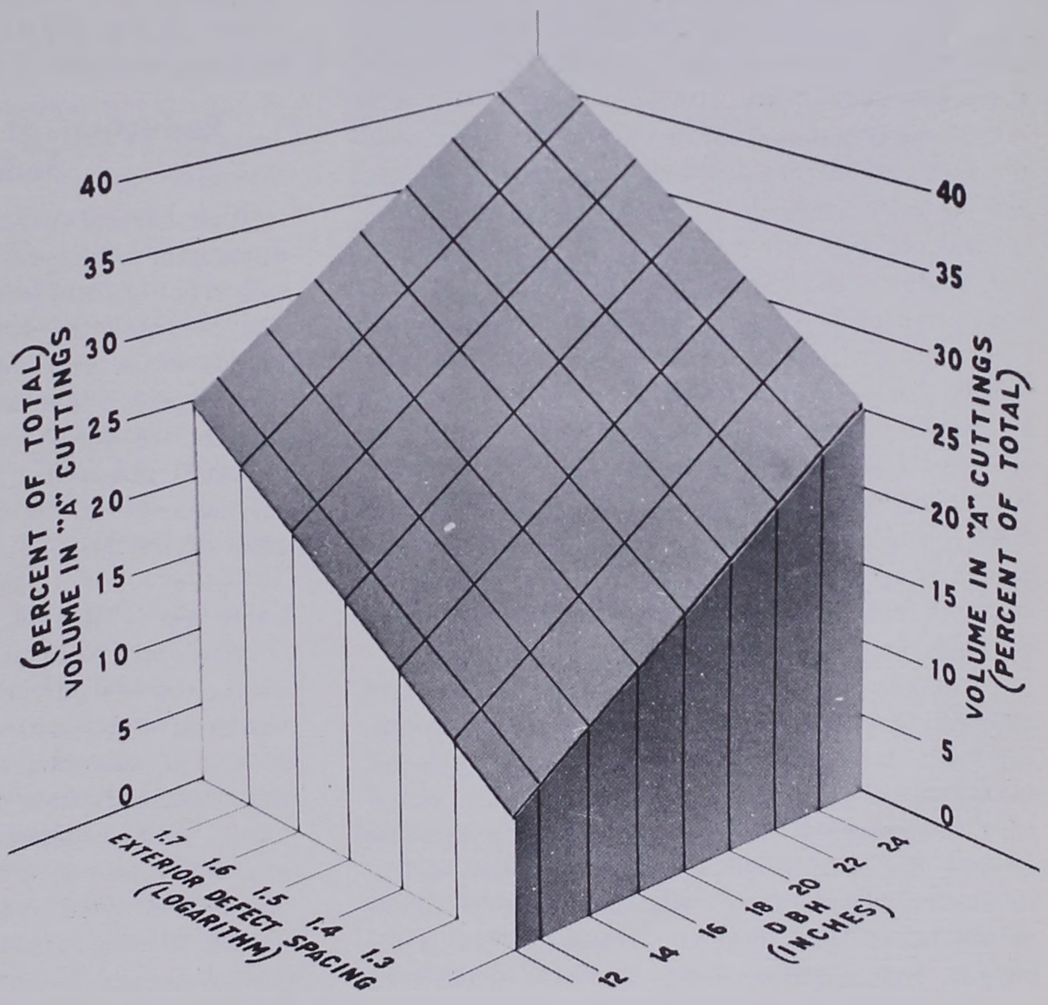

FIGURE 31. — This three-dimensional model illustrates the general type of relationship between two tree stem characteristics (d.b h. and defect spacing) and an expression for wood quality. A class-A cutting is defined as a clear one-face cutting at least 3 inches wide by 80 inches long or 4 inches wide by 60 inches long.

To date, at least 50 multiple regression analyses have been made on electronic computers to determine: (1) which of these stem characteristics are most highly correlated with quality, and (2) how these characteristics can best be expressed quantitatively — for example, whether a defect should be measured by length, width, or area. Both of these problems are near solution. An example of one of the simpler relationships found is shown in figure 31.

The next step will be to develop the equations for each wood quality class. And finally we must determine whether they are applicable to the entire range of sugar maple.

WATERSHED MANAGEMENT

Research in watershed management got its start at the Lake States Forest Experiment Station in the early 30's. Work was concentrated on the serious runoff and erosion problems in the Driftless Area of southwestern Wisconsin and southeastern Minnesota. The program was small in scope and area covered. It was also of short duration. These studies indicated that runoff and erosion were accentuated by the removal of the protective forest cover from the steep hillsides. They suggested the need for changes in land use management. With the advent of World War II, all fieldwork was shut down.

Although methods of preventing surface runoff and soil erosion are still important, they are not the only needs in watershed research. Trends in land use and demands for water have changed. The vastly expanded use for households and industry as well as for recreational needs has created new and conflicting demands for the available supply. These conflicts cannot be solved without a fund of more precise information on the effect of forest management on water quality and quantity. In recognition of the new and difficult watershed problems, the watershed management research program was reactivated 6 years ago. The research effort today reflects this broader scope of watershed problems.

Although the effort is relatively new, early research accomplishments provide some promising leads. Indications are that many current forest management practices are compatible with watershed management needs. Thinnings to increase growth and cutting spruce, using east-west drifts, to insure regeneration will also enhance snow accumulation for subsequent release to the water regime. Reforestation of idle and abandoned land is a first step toward ameliorating the amount of concrete freezing in the forest cover. Studies in bog hydrology are beginning to indicate some of the key factors in water behavior that may in turn influence its manipulation for both tree growth and water supply. Studies in ground water flow and recharge currently under investigation are designed to provide guides to practices that may influence the ground water regime.

These new and unique phases of watershed research are discussed by individual research projects currently underway.

Reduction of Storm Runoff and Sedimentation

Our current program of research on the reduction of storm runoff, erosion, and sedimentation from the unglaciated area of the Lake States was activated in cooperation with the Wisconsin Conservation Department. A field unit of the Station was established at La Crosse, Wis. After 4 years, we now have a balanced watershed management research program underway, aimed at solving some of the complex land-use water problems of the area.

Land Use — Key to Runoff and Erosion

The early work at La Crosse showed that land use is the key to the soil and water problems in this area of two-storied farming and erosive loessal soils. For example, a watershed study indicated that overland flow from protected forest land hardly ever occurred, even on the steepest slopes and under severe storm conditions. A recent survey of 40 wooded watersheds and current research on the Coulee Experimental Forest substantiate this. Woodland gullies, a prominent feature of the

Driftless Area landscape, are now known to be the direct result of runoff from upland fields (fig. 32).

Two approaches for correcting this condition are under investigation:

1. Spreading water from upland fields so that it doesn't concentrate and develop gullies with the accompanying erosion. We are now testing such water-spreading techniques.

2. Changing land use so that opportunity for rapid runoff and concentration of water is reduced. We plan to test effects of land abandonment and reforestation in the area.

A changing pattern of land use that may influence the amount of runoff is gradually showing up in the area. There is an increasing acreage of abandoned farmland, mostly on the steeper slopes. Watershed studies now underway will determine the influence of this land abandonment on runoff and erosion.

At the same time, we are studying the effect of converting this land to trees. Since little is known about establishing trees on these steep, abandoned slopes, a first important step is to determine the fastest and most economical ways of doing this. Research on the problem was started 2 years ago on the Coulee Experimental Forest near La Crosse, Wis. Planting survival for different species by different planting methods and on different sites is being studied. To date, 13 species have been planted or seeded. The trials also include five ground-preparation methods, two transpiration retardants, and mechanical shading. Especially strong contrasts on species survival are appearing on the dry, rocky, south slopes where first-year survivals range from 34 to 100 percent.

The established plantings will then provide clinical material for studying the effects of tree planting on soil and water and for evaluating growth by the various species on the various sites.

New Instrumentation, a Continuing Need

In our present program, we are devoting some effort to improving the techniques and instruments needed for watershed research in this rough terrain, where runoff is intermittent and sedimentation is high. Some developments are:

1. Automatic triggering devices for both water-level and rainfall recorders. These require fewer trips to the field for chart changing.

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FIGURE 32. — *Upper* — Gully and rock-run caused by storm runoff from upland field. *Lower* — Completely forested watershed shows no sign of runoff at outlet.

2. Inexpensive weirs and flumes for measuring waterflow. These permitted us to install 30 weirs and flumes and 22 observation wells at limited cost.

3. Stage sediment samplers adapted for use with runoff flumes. These give an estimate of sediment in flashy streams where integrated samples are almost impossible to obtain.

Springflow, an Important Water Resource

Although uncontrolled surface runoff is the major watershed problem, springflow in the Driftless Area is an important part of the water economy. Information on its behavior and on the

factors affecting its supply will indicate whether we can increase springflow by reducing uncontrolled surface flow. Two distinct types of springs have been observed; they have been termed "lower" and "upper" in relation to their elevational location on the Coulee Experimental Forest. The discharge from the lower spring in southwestern Wisconsin is at a relatively low level during the winter (figs. 33 and 34). In the spring (April-May), it rises abruptly and generally reaches the highest level of the year. This peak is followed by a declining trend during the summer. Late summer and fall rains recharge the soil and ground water reservoirs slightly during late Oc-

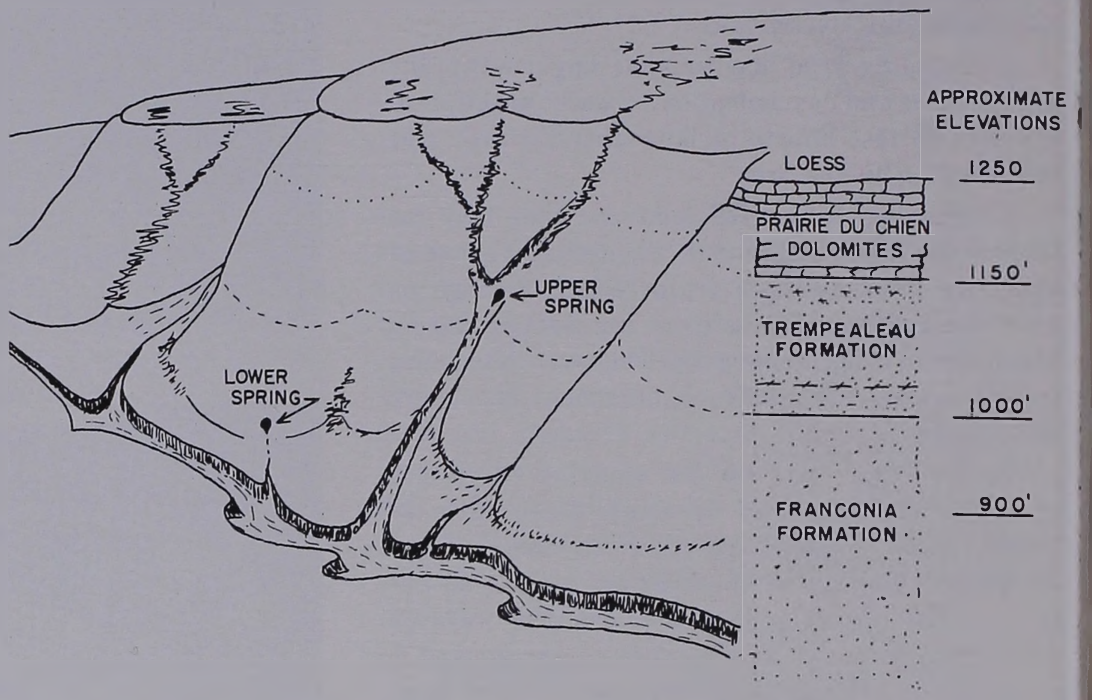

FIGURE 33. — Schematic diagram showing typical land forms on the Coulee Experimental Forest. Locations of upper and lower springs are shown in relation to topography, geology, and to each other.

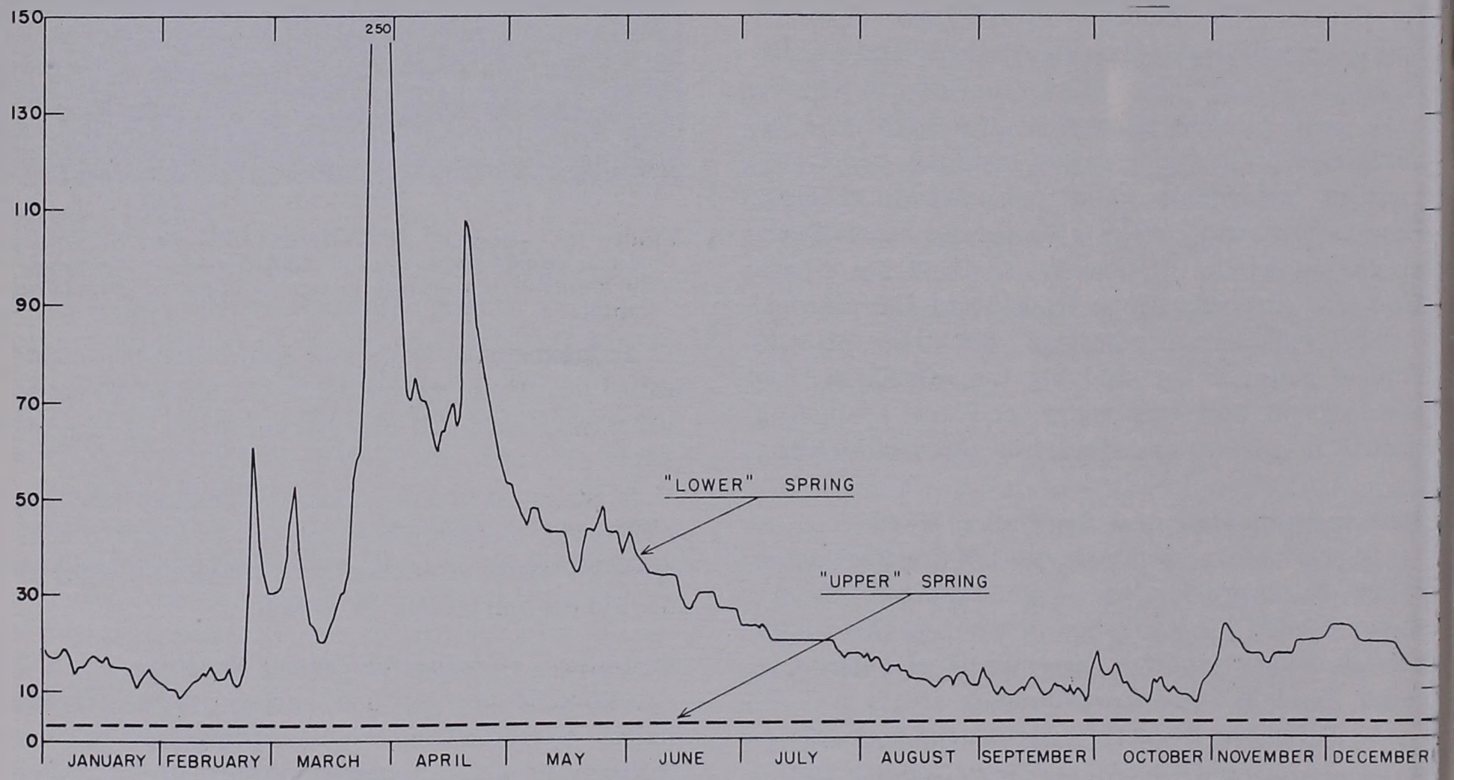

FIGURE 34. — Hydrograph of daily discharge for an upper and a lower spring on the Coulee Experimental Forest.

tober or early November. During the winter months there is a gradual depletion. The measured flow from the upper springs on the same area is strikingly different. Records over a 3-year period indicate that their discharge was relatively constant, with little change throughout the year. Further investigation will help determine whether manipulation of vegetative cover can modify the pattern and contribution of these two types of springs to the total water supply of the area.

An unsolved problem is how to determine the watershed area that contributes to a given spring. We are attempting to do this by drilling observation wells into the ground water table to map ground water contours. This will define the watershed area contributing to springflow. We will then be able to study the effects of land use and cover manipulation on springflow — the ultimate objective of our springflow research.

Bog and Swamp Hydrology

Nearly 40 years ago the Station investigated the effect of the bog drainage program on forest growth. Little thought was given to bog hydrology at that time. It wasn't until recent years that peat bogs of northern Minnesota were again a focus of research for other than silvicultural studies. Now the Station has an active program of bog and swamp hydrology research concerned with the effects of land management practices on the timing, quantity, and quality of streamflow from bogs and their contribution to ground water recharge.

To get at the basic answers, the bog and swamp hydrology project at Grand Rapids has concentrated research on two major fronts. One of these is to understand the water behavior and general hydrology in watershed areas containing swampland. Several small bog watersheds have now been observed for 2 years and are already furnishing valuable preliminary information. These swamps will be altered and the effect of treatment on the water resource measured. The other major field of research deals with understanding the basic physical and hydrologic properties of organic soils — a vast unknown. Our studies of peat soils are generally short-term experiments carried out on the experimental bog watersheds and in the laboratory. Several of these have already been completed and have supplied new information on peat soils that helps explain water behavior in the swamp watersheds.

Bog Hydrology Studies — Additional Instrumentation

Five bog watersheds have been instrumented on the Marcell Experimental Forest. They have been equipped with 5 streamflow measuring gages, 5 recording and 36 nonrecording bog wells, a network of rain and snow gages, and 2 field weather stations. One of the bog watersheds is unique in that it is instrumented with two outflow gages because it has two outlets. Both standard 120° V-notch tank-type weirs and 2-foot H-type flumes are used. The H-type flume (fig. 35), generally used on agricultural watersheds, has been installed on several bog outlets because of the typical low-gradient stream channels and the wide range of streamflow from these bogs.

In addition to the installations listed above, a major project of deep well drilling in the upland portions of all watersheds was started. Nine wells have been drilled to date. A portable well-drilling rig, capable of augering to depths of 65 feet, is now being used to explore the surface geology and the deep underground aquifer in each watershed. Figure 36 indicates the relationship between one of the bog watersheds and the deep underground water table. Here, the regional ground water table is several feet below the deepest part of the bog. Thus, the peat bog and its water table are perched within a shallow basin in the glacial till. Early observations indicate that probably water moves slowly through the clay till to recharge the deep water table.

On the other hand, observation wells recently

FIGURE 35. — An H-type flume installed at a bog outlet in northeastern Minnesota.

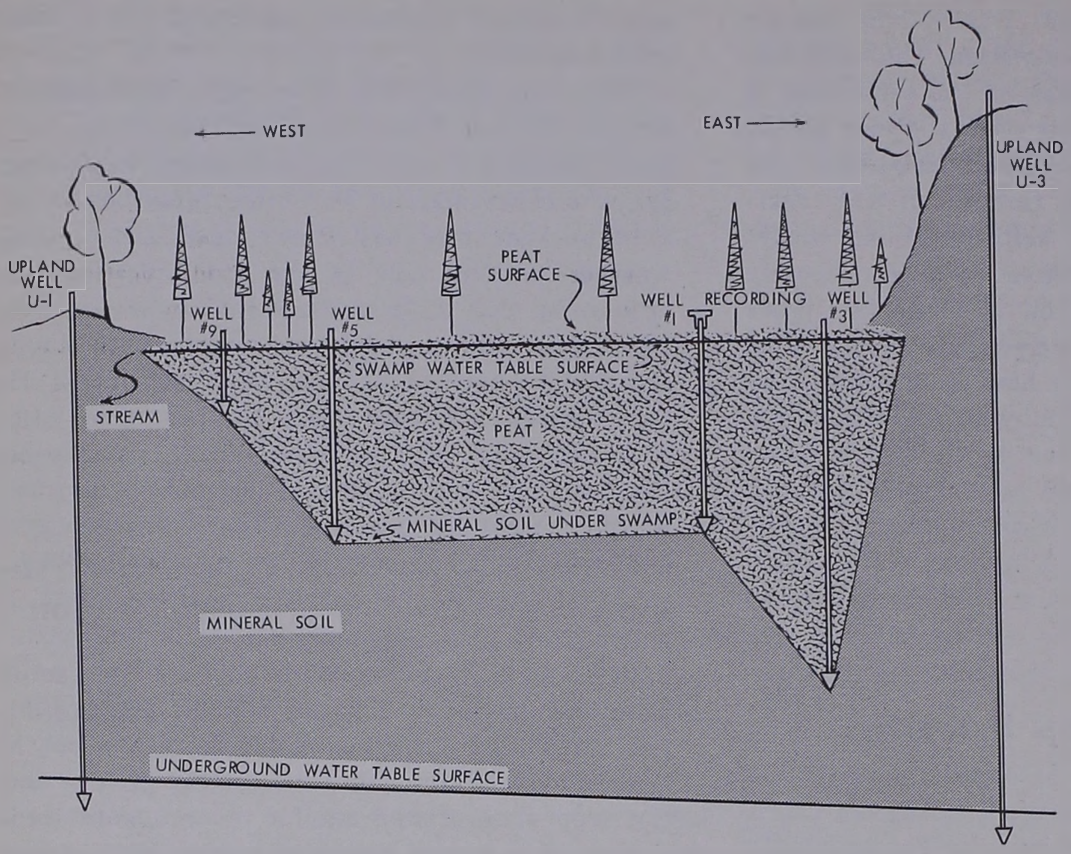

FIGURE 36 — Cross section of Watershed S-2, Marcell Experimental Forest.

drilled in another bog watershed indicate that the bog water table is merely an extension of the general underground water table. In this area, relationships between the bog and recharge of the general ground water table are more complex.

Each of these bogs will have different hydrologic characteristics, and each may react differently to cover-type manipulations. Each will have to be calibrated with similar bog types. The long-range goals are to predict which bogs will react to land management changes and what these reactions will mean to the general hydrology of the area.

Physical Properties of Peats

A New Field of Research

The soils of a watershed are the storage reservoir for the rain and snow that fall and eventually become streamflow and ground water. The characteristics of this soil mantle, how fast it receives precipitation, how much it stores, and how fast water moves through it, all affect the end result of the watershed — water yield. Bog watersheds are no exception. However, the important soil reservoir on a bog watershed is an organic peat soil, and very little is known about its hydrologic characteristics. To interpret the hydrology of these soils properly, research on the basic physical properties of different types of peat is now underway.

New studies, initiated within the last few years, already have yielded new and significant information about the physical properties of peat soils. Figure 37 shows the large amount of water held by peats. It also indicates the importance of using moisture content per unit volume when discussing peat soils because of the great variability of moisture by weight and the possibility of drawing misleading conclusions. Most of the information available, however, has expressed water content on an ovendry-weight basis. The illustration shows that the relative order of water storage capacity is just the *opposite* when a volumetric expression is used instead.

These same studies in physical properties indicated that both water retention and bulk density (wet volume basis) at saturation varied greatly for peat types. Undecomposed sphagnum moss peat had many large pores which lost their water easily. Partially decomposed moss peat, aggregated peat, and sedge peat were much more dense, containing many small pores which were not easily drained. Thus, a specific change in water table level in the loose, porous, moss peat

would involve a great deal more water than the same change in water level in the more dense aggregated and sedge peats.

The data point out some interesting facts about the watershed aspects of organic soils for storing snowmelt and runoff waters. In one of the bogs studied, a great deal of storage capacity is made available in the moss peat horizons if the water table is lowered a short distance from the surface. However, additional lowering of the water table into more compact aggregated and sedge peats provides relatively little additional storage capacity. Thus, the role of a particular bog as a storage reservoir will depend not only on the depth to which the water table drops, but also on the type of peat material in the deposit.

These data also indicate the importance of peat type to drainage. Although a great deal of water can be drained from moss peats similar to those studied, simply lowering the water table would drain only a very small part of the water from an aggregated or sedge peat.

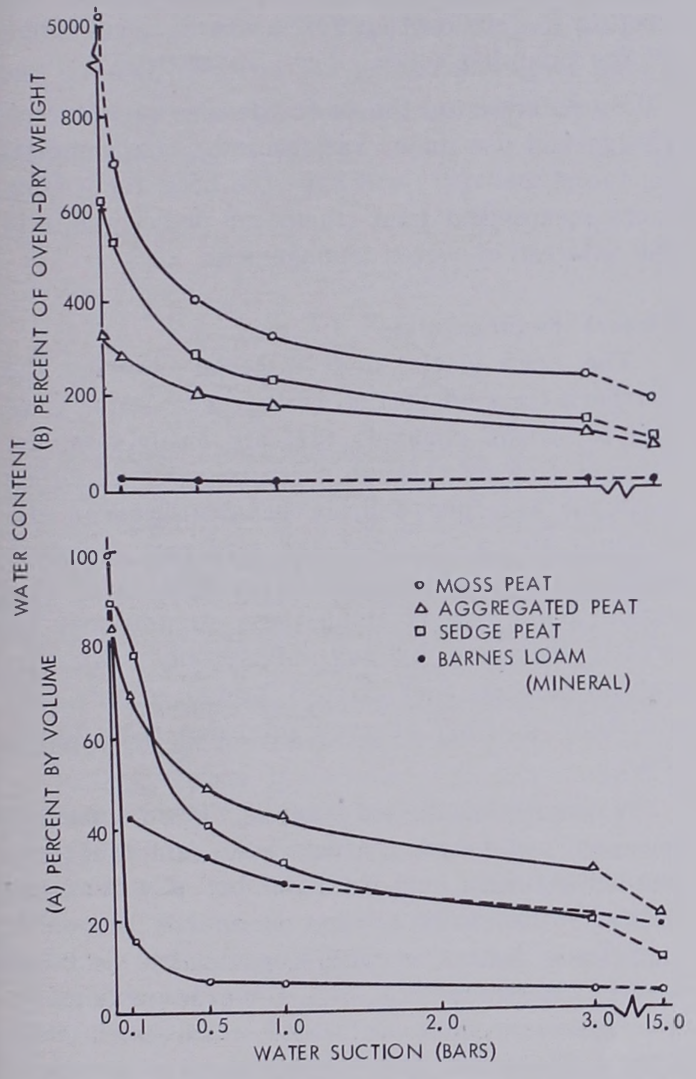

FIGURE 37. — Water contents of several peat materials and a mineral soil expressed as (a) percent by volume and (b) percent of ovendry weight.

Rates of water movement through these different peat materials are also being investigated. Different types of piezometers as well as laboratory methods are being used to study vertical and horizontal hydraulic conductivities in various peat materials and at different soil horizons. Such basic studies of the physical and hydraulic properties of organic soils will enable accurate interpretation of watershed characteristics and tell us why our bog watersheds behave as they do.

Effects of the Forest on Ground Water Recharge and Streambank Erosion

A unique watershed research program was undertaken in cooperation with the Michigan Conservation Department in Lower Michigan. This effort was initiated in recognition of the fine-quality water that originates in glaciated forest areas with deep, sandy, porous soil and fills the lakes and streams. It is this porous drift material, however, which gives rise to the two primary watershed studies in the area: (1) the influence of forest type and management practices upon ground water, and (2) factors affecting streambank erosion and sedimentation along the streams flowing through the loose unconsolidated drift.

Ground Water Hydrology Studies

In these areas of sandy moraines and outwash plains, ground water seepage sustains streamflow. Thus, the control of streamflow depends upon the control of ground water. The specific effects of forest type, cover changes, and management practices on ground water recharge are unknown and worthy of serious investigation.

These effects are being studied under two ground water conditions: (1) where ground water is sufficiently near the surface so that tree roots can obtain moisture directly from the ground water reservoirs, and (2) where ground water is deep and beyond the influence of tree roots. Measurements of the fluctuations of the ground water table due to rainfall, snowmelt, and evaporation and transpiration losses are also under investigation. Involved are: 108 wells, of which 8

have recorders; and 12 soil-moisture sampling points, each with 5 to 7 levels of sampling.

When the ground water patterns under existing conditions have been determined, selected areas will receive partial and complete reductions of forest cover or will be converted to different forest types. The resulting changes in ground water behavior will indicate the consumptive use of the existing forests and the increases or losses in ground water supples that may be obtained by managing or converting the existing stands.

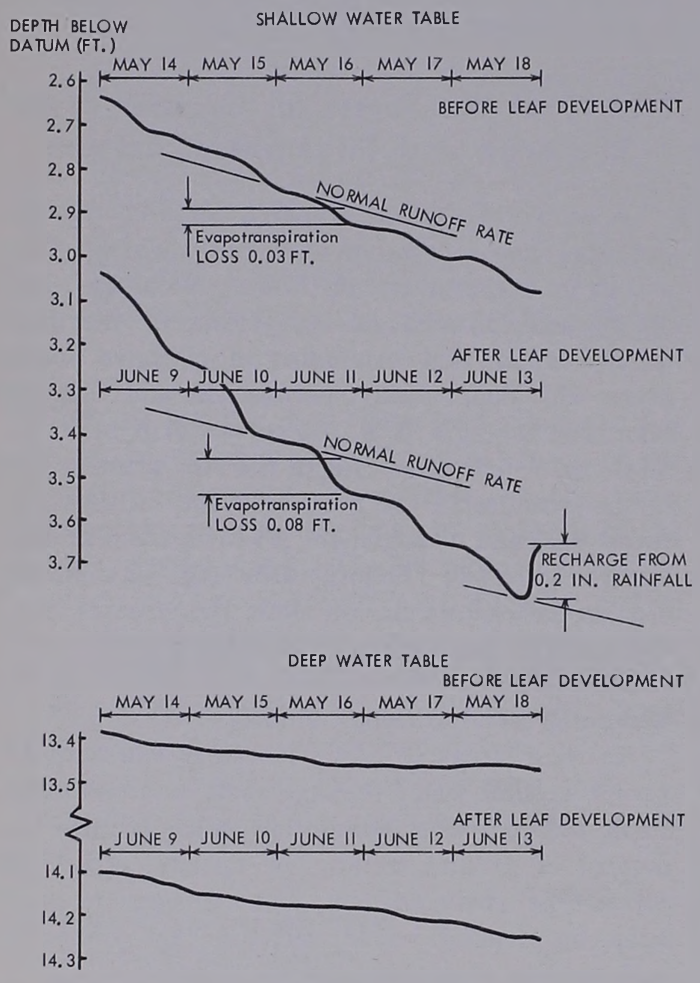

FIGURE 38. — Recession of deep and shallow water tables before and after leaf development.

An illustration of some of the seasonal variation in water used under a shallow water table area with a swamp hardwood cover is shown in figure 38. Before the leaves are developed, the decline of the shallow water table is principally due to gravity runoff. Evaporation from the soil surface and transpiration by early herbaceous vegetation produce an additional drop during the sunlight hours of about 0.03 foot over the normal runoff rate. In June, when the hardwood leaves are fully developed, the daily loss due to evapotranspiration increases to approximately 0.08 foot per day. Thus, these shallow water table areas may contribute little to net increment of the ground water supply and may, in fact, actually utilize water supplied from other deep aquifers during dry periods.

In a deeper lying aquifer nearby, the roots cannot utilize the deep ground water. Water loss to transpiration is decreased. Thus, these areas may act as producers and conservers of water.

There is a more rapid decline in June in both deep and shallow aquifers. In the deep aquifer this is due to the greater gradient toward the neighboring shallow water-table area where the water table is dropping because of accelerated use. The drop in the shallow aquifer is merely a reflection of the pumping action of the vegetation.

By determining the basic patterns of water recharge and use under various soil cover complexes, forest managers will have the basis for writing more meaningful land treatment prescriptions in the interest of water management.

Stream Sedimentation

The deep glacial drift material covering the northern forested portion of the Lake States gives rise to stream channels that are easily erodible. Streams flowing through these unstable materials maintain a rather delicate balance between the stream's ability to erode and transport sediment particles and the natural forces that resist this action. Bank erosion along these streams may be greatly increased by any interference with this natural balance, such as road, bridge, or dam construction; grazing; or even intensive recreational use.

A recently completed study of the relationships between watershed characteristics and the suspended sediment load for a number of watersheds indicates that bank erosion is one of the more significant factors contributing to the sediment load of the stream (fig. 39). For example, a study in a 134-square-mile watershed in Michigan, with 6,200 feet of eroding banks, indicates that the average sediment concentration could theoretically be reduced 47 percent by stabilizing the eroding

banks. Whether this reduction can be attained will be tested after the eroding banks in the watershed have been treated.

Of the suspended sediment remaining in the stream after that portion attributed to eroding banks has been removed, 56 percent comes from agricultural land (28 percent of area), while the remaining 44 percent comes from forest or other wild land (72 percent of area).

Other watershed characteristics influencing the suspended sediment concentration in the sample watersheds include stream discharge, rising or falling stage, the type of soil occurring within the watershed, and the proportion of watershed area under cultivation and pasture.

This study involves 20 sampling stations on 11 small streams. To date, 840 sediment samples have been collected, showing a range from less than 10 to 3,700 parts per million.

FIGURE 39. — Measuring velocity and quantity of streamflow in the Tobacco River watershed. Sediment concentrations in northern trout streams generally increase with an increase in stream discharge.

FOREST FIRE RESEARCH

When the Station was established in 1923, research on forest fires was one of the first and most important activities. By 1940, the combination of research, improved suppression methods, slash disposal, and access road construction had greatly reduced the number of fires and acreage burned on both State and Federal lands. Since that time significant reductions in number of fires or area burned have not been evident.

Recent increases in volume of timber harvested, forest visitors, and number of acres going into pine plantations combine to create more hazardous conditions. In addition, the Lake States is confronted with many questions concerning the beneficial uses of fire. These subjects, and others, are summarized in "A Forest Fire Research Program for the Lake States" recently prepared by the Lake States Committee on Forest Fire Research.

As a broadened fire research program gets underway at the Station, attention is being given to fuel measurement, fire weather, firebreak maintenance, equipment evaluation (fig. 40), and prescribed burning. Some of this work is briefly described here.

Fuel Volume in Pine Plantations

To predict fire behavior and intensity, the volume of fuel per unit area must be known. The Station is continuing to collect data on fuel volume in red pine plantations (fig. 41) and will soon extend these studies to jack pine and mixed stands. The results to date indicate, for example, that a 20-year-old, well-stocked red pine plantation on a good site may contain an average of 27½ tons of fuel per acre, excluding the main stems of the stand. Of this, the green crowns (needles and branches) comprise 56 percent; dead branch wood, 19 percent; surface litter, 11 percent; and the duff litter, 14 percent. With sufficient

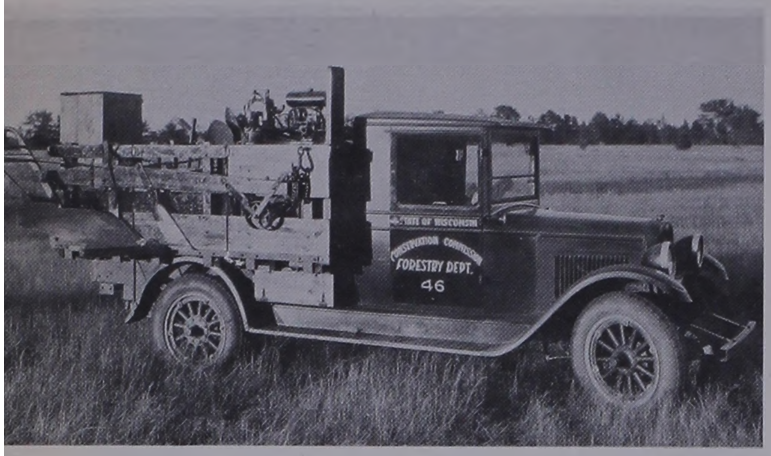

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FIGURE 40. — In the early days the truck shown above was in general use for transporting men and equipment to wildfires. It carried handtools, back-pack pumps, a center-breaker plow, and a small pumper unit for use where a water source was available. Today, although the same types of tools are used, they have been greatly improved to make them more effective and serviceable. In addition, specialized transportation equipment has been developed. The Bombardier tractor *(bottom)* moves men and equipment in swampy areas not only for fire control work but also for many other administrative needs such as planting trees and surveying timber and game resources.

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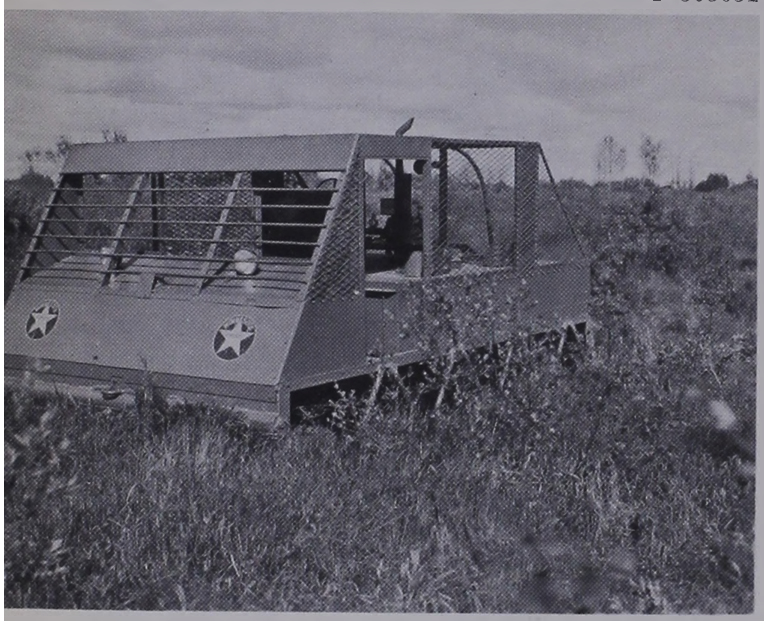

data of this kind tables may be prepared to show the volume of slash and the total fuel volume that may be expected in a given stand when the stand is thinned or cut to a predetermined basal area.

Chemical Firebreak Maintenance

Firebreaks are an important supplemental fire protection measure in the Lake States. Their maintenance by mechanical means, the best method so far, is expensive. The use of soil sterilant chemicals may eventually provide a partial solution to this problem.

For a chemical to compete with mechanical firebreak maintenance it must provide reasonably good vegetation control for at least 3 years with only a light reapplication of chemicals needed to extend control for another year or two.

Certain chemicals have shown promise in past tests and are currently being given additional trial on some operational firebreaks in Minnesota. The chemicals presently being tested appear to be selective in nature. That is, they are probably not completely effective on all soil types or all cover types. For this reason, the current testing program is concentrating on three soil types, each supporting vegetation that presents a problem from a firebreak standpoint. The three soil-cover types include: (1) Jack pine sand plains, (2) heavy soils with cutover birch-aspen and bracken fern, and (3) dense grass cover on sandy loam.

The results will be evaluated in terms of overall cost, convenience of chemical application, and, of course, chemical effectiveness.

Research on Prescribed Burning

The success of prescribed burning in the Lake States depends to a large extent upon the continued development of a sound scientific basis for determining *where* and *when* to burn to realize established objectives.

During 1962 the fire research staff provided technical help in planning and executing prescribed burning operations on both Federal and State forest lands in Minnesota. This work will be extended to National Forest land in Wisconsin during the coming year.

Prescribed fire may be used successfully for hazard reduction, site preparation, type conversion, insect and disease control, or management of game habitat. As the term "prescribed" indicates, burning must be accomplished for a definite purpose under specific conditions of fuel moisture and weather.

Much of the prescribed burning research effort is currently directed toward finding out more about: (1) The response of various cover types to controlled application of fires of varying intensity, and (2) how best to predict when to burn to achieve the right combination of fire intensity and resulting effect on vegetation. Through these

studies, research is attempting to eliminate some of the guesswork in selecting areas where prescribed burning will have a good chance for success and in determining precisely when weather conditions are favorable.

Experience to date indicates that: (1) Jack pine cutovers can be effectively burned in the summer after 6 to 8 days without appreciable rain. Under these conditions, much of the surface litter is consumed and an acceptable site is prepared for direct seeding or planting. (2) Summer burning, after 2 weeks of dry weather, eliminates competing brush species from certain areas and exposes mineral soil for regeneration purposes. (3) Prescribed burning for hazard reduction can be accomplished following 3 to 4 days without appreciable rain. Under these conditions, the flashy fuels are consumed, leaving the heavier fuels to decay slowly. This type of burning can also be done under less hazardous burning conditions and still be completely effective.

In addition to the primary benefits of prescribed burning mentioned above, these controlled fires provide an opportunity for organized fire suppression crews to function as a team and observe fire behavior, otherwise seen only on wildfires. Training in equipment use and testing of new equipment are also important secondary benefits.

FIGURE 41. — Here sample tree crowns are weighed and related to basal area of the stand.

FOREST DISEASES

Forest disease research is a relatively new area of work at the Lake States Station. It became a part of our program 8 years ago. At that time the disease research staff consisted of one full-time man, and the program was centered on one project — hypoxylon canker of aspen. Since then the program has expanded to include a staff of eight full-time research workers devoting attention to the several major problems discussed in this report. The lack of an earlier emphasis on disease research accounts for the many problems now demanding attention.

Major accomplishments in past years include active participation in cooperative research that has led to a determination of the cause of maple blight, development of an effective fumigation method for controlling nursery root rots, and practical application of microclimate theories to blister rust control. Important findings include the discovery of stalactiform rust on jack pine, information on races of white pine blister rust and on the rate of spread and damage for oak wilt, decay relationships with wounds on sugar maple, and detailed evaluation of disease growth impact. The greatest disappointment over the years has been the lack of substantial progress in resolving the hypoxylon canker problem.

During the past 2 years major new studies have been initiated and are now well underway on stains and decays in sugar maple and the use of antibiotics to control white pine blister rust. Studies have been concluded or will soon be completed on maple blight, oak wilt, and nursery root rots. In addition, work is continuing on several long-term studies. The more important of these are maple dieback, hypoxylon canker of aspen, stem rusts of jack pine, white pine blister rust genetics, and the influence of microclimate on

white pine blister rust.

The Station's disease research program is now centered in three major projects:

Northern hardwood disease research is assigned to the Northern Hardwoods Laboratory at Marquette, Mich. Dr. John H. Ohman is the Project Leader. Assisting him is Dr. Kenneth J. Kessler, Jr.

Conifer disease work, headed up by Dr. Eugene P. Van Arsdel, is centered in St. Paul except for the white pine blister rust antibiotics research at Rhinelander, Wis. Two men stationed there, Dr. William R. Phelps and Mr. Ray Weber, have recently been employed by the Station to devote full time to testing the effectiveness of antibiotics in the control of blister rust. Dr. Van Arsdel will continue to devote a major portion of his time to research on the influence of microclimate on white pine blister rust. Mr. Darroll Skilling, who has now completed his maple blight studies, will turn most of his attention to blister rust genetics. The conifer disease project also includes responsibility for work on diseases of seeds, seedlings, plantations, and trees of the Northern Great Plains. Currently activity on these problems is very limited.

Research on aspen diseases is also centered at St. Paul under the direction of Gerald W. Anderson.

The following is a summary of the current status of the more important disease research projects.

Northern Hardwood Diseases

The northern hardwood disease research project is now well settled in quarters at the new Northern Hardwoods Laboratory at Marquette, Mich. The work of staffing, equipping, and arranging the facility for pathological research is progressing. While the laboratory is small, it is well equipped and adequate for the present staff. The move to Marquette places the project in the heart of the northern hardwoods area and also enables project scientists to utilize more easily the excellent research areas available on the Station's Upper Peninsula Experimental Forest.

Sapstreak Disease Found on More Sugar Maples

The sapstreak disease of sugar maple, caused by the fungus *Ceratocystis coerulescens*, was first discovered in the Lake States on a single tree in 1960. Since then, the Station disease research staff has been on the alert for additional infected trees. During the summer and fall of 1962 several were found and verified. Indications are that this disease may have a great potential for damage to sugar maple in this region. The effects are twofold: Most infected trees are eventually killed (fig. 42), and lumber sawn from them is of little value because of stain in the infected portions (fig. 43). Even trees harvested before death occurs are badly stained.

In one sample of 145 sugar maple trees cut during selective logging on the Upper Peninsula Experimental Forest, 10 trees were found to be definitely infected. Several others had died previously for no apparent reason. Because of decay by saprophytic organisms, it was not possible to determine whether sapstreak was responsible; but this appears to be the most likely explanation.

Exploratory studies to determine the extent

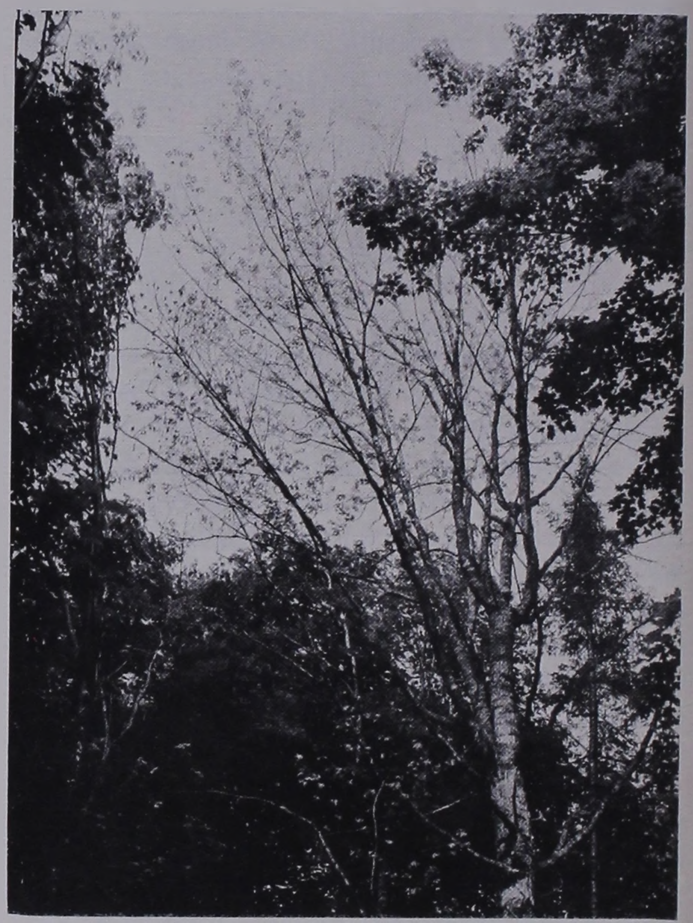

FIGURE 42. — A sugar maple with the sapstreak disease. The small, sparse foliage is typical of the last stages of the disease. This tree will probably be dead within 1 year.

FIGURE 43. — Cross section of a sugar maple showing the stain and discoloration associated with infection by the sapstreak disease.

and prevalence of this disease are now underway. The only sizable area examined to date is the western part of the Upper Peninsula of Michigan where logging operations at 15 locations were checked. Approximately 1,400 recently cut stumps were examined for evidence of the disease. Of these, only one was found to be infected. Although it is too early in the study to reach any definite conclusions, evidence to date seems to indicate that the fungus may enter trees primarily through logging wounds. This could account for the great difference in prevalence between the Experimental Forest and other areas examined. Northern hardwood stands on the Experimental Forest have been cut selectively 2 to 4 times, and the residual trees in those stands had more logging wounds than did trees in other stands examined. Most of the latter were clear cut in the early 1900's and are now receiving their first selective cut. Plans are to continue evaluating the potential of this disease and attempt to determine whether there is a relationship between wounding and infection.

Fundamental Research on Maple Dieback Progressing

Intensive studies aimed at determining the cause of maple dieback are being continued. Under investigation are factors such as root, branch, and twig pathogens, mycorrhizal disturbances, soil compaction, and soil moisture relations.

As is often the case in complex problems, a great deal of basic knowledge must be uncovered before proceeding further. An example of such work is the investigation of mycorrhizae of sugar maple. Mycorrhizae are a symbiotic association of plant roots and soil-inhabiting fungi. Prior to this work the internal anatomy of sugar maple roots containing the mycorrhizal fungus was unknown. Dr. Kessler reported on his mycorrhizal research at the 1962 meeting of the American Phytopathological Society and is preparing an article on the same subject for publication in a scientific journal.

A 12-acre tract on the Experimental Forest has been instrumented with soil-moisture measuring devices as part of an intensive study aimed at learning more about the relationship of various soil moisture regimes and the dieback complex.

Results of the annual dieback examinations conducted on the Upper Peninsula Experimental Forest for the past 5 years indicate that top-dying had become stabilized with few significant increases in the last 3 years.

The maple dieback problem is causing considerable concern throughout the range of the northern hardwood type and is receiving some attention in Eastern Canada and the Northeastern States as well as the Lake States.

Decay and Stain Need More Research

Work is continuing in a study designed to determine the long-term effects of logging wounds on an old-growth stand of northern hardwoods cut selectively in 1955. Shortly after logging, all trees in the residual stand were examined for wounds and a number selected as sample trees. Sample trees will be dissected 5, 10, 15, and 20 years after wounding to determine the extent and types of rot and stain traceable to the wounds, and an attempt will be made to correlate extent of damage with various kinds and sizes of wounds. Most of the trees in the study are sugar maple and yellow birch. Previous studies have provided some information of this type for sugar maple, but none is available for yellow birch. During 1962 a manu-

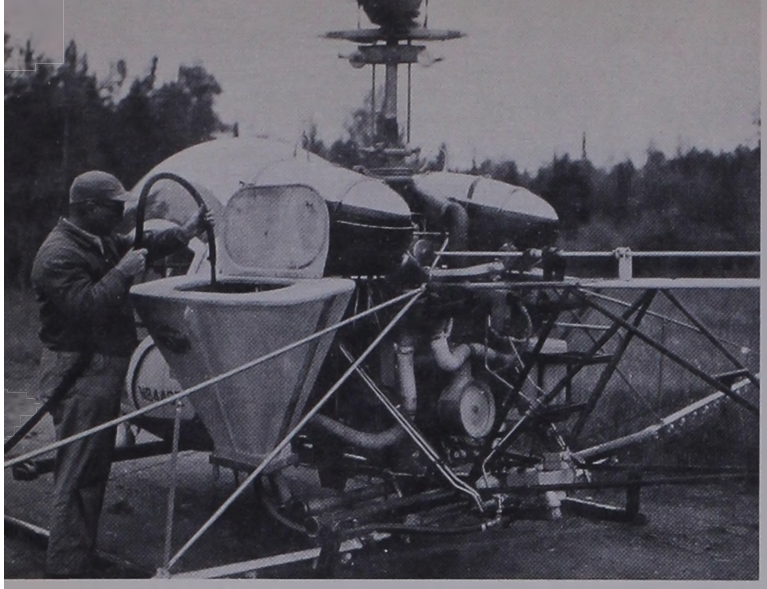

FIGURE 44. — Loading a helicopter with an antibiotic solution to be applied in a test. Although about 10 gallons of solution are applied per acre, the actual amount of antibiotic amounts to only a few grams per acre treated.

script reporting results of the first dissection was accepted for publication by the Journal of Forestry.

The study of microorganisms present in internal defects of sugar maple, conducted jointly with the Station's Division of Forest Utilization Research, was continued in 1962. The isolation phase for the second 45-tree sample was completed, and the identification of the organisms recovered is progressing.

Future plans are to increase the amount of research on the decay and stain problems of northern hardwoods, since they have the greatest disease impact on northern hardwood volume and quality.

Conifer Diseases

During the past 2 years the Station's program of research on conifer diseases has been, to a large extent, a continuation of previous work. The most important new project is the development of a large-scale study on the use of antibiotics to control white pine blister rust.

Antibiotics Being Tested for Blister Rust Control

The discovery that certain antibiotics could kill a blister rust infection on pine after the fungus had become established in the tree is a major breakthrough in the use of chemicals to control tree diseases. Most of the work with antibiotics has been done on western white pine in Idaho. Early tests of these chemicals on eastern white pine, however, produced many inconclusive results. Consequently, an intensive testing program was begun in collaboration with the North Central Region of the Forest Service to determine whether a specific treatment could be developed that would be consistently successful. In this new study a series of tests is to be established, each one designed to take advantage of information gained from the earlier ones. During the 1962 field season three tests were installed.

Aerial treatments were applied by helicopter to seven 4-acre plots on the Superior National Forest in the spring (fig. 44). These tests will show comparative effects of phytoactin and cycloheximide derivatives and the fuel oil emulsion and water carriers used to dilute these antibiotics. Aerial treatments made by other research groups in this region will aid in evaluating this method of antibiotic application.

The largest test in 1962 was established in a plantation near Merrill, Wis., in cooperation with Fromm Brothers. This is a basal stem spray test involving different concentrations of phytoactin, cycloheximide, and derivatives applied at different seasons of the year. Many hundred carefully selected trees will be individually treated in accordance with a complex statistical design.

Although the aerial foliar spray and the basal stem spray tests outlined above represent the two principal application techniques used with antibiotics, a third method was employed in a test established south of Rhinelander, Wis. This method may possibly be better than the basal stem method for from-the-ground application, particularly on smaller trees. Trees up to 10 feet tall were completely drenched (needles and stem) with various concentrations (including very high concentrations) in an effort to get more antibiotic into the trees. Three antibiotics — the semicarbazone derivative of cycloheximide, phytoactin, and streptimidone — were applied at 12 different concentrations.

The bioassay of various parts of treated trees is one of the more basic aspects of these studies. At specified intervals of time after treatment, selected trees are dissected and bioassayed to determine the distribution and persistence of the antibiotics. This should provide valuable information on how the antibiotics move through trees and hence how they should be applied and where cankers might be killed (fig. 45).

Although major emphasis this past year has

been on getting new tests started, attention has also been given to continued evaluation of the older, smaller scale tests established in previous years. It takes a long time to determine whether cankers are killed by these antibiotics, and final results are not yet available although some preliminary data have been obtained. These older tests employed the basal stem method of application.

The 1959 test using cycloheximide on the Flambeau River State Forest in Wisconsin indicates increasing effect on cankers as the concentration of the chemical was increased. This reaction was limited to cankers to which the antibiotic was applied directly. No effect was evident on other cankers on the same tree where the antibiotic would have to have been translocated from the treated portion of the trunk to produce an effect.

The 1960 Flambeau River State Forest tests give preliminary results similar to those of the 1959 tests. The 1960 tests compared concentrations of phytoactin from 100 to 800 p.p.m. and cycloheximide at 200 p.p.m. First-year results show increasing effect on the cankers with increasing chemical concentration and a lack of transport to cankers on untreated portions of the tree.

Although these results indicate that the antibiotics are having an effect on cankers when applied directly, the apparent lack of effect through translocation to other parts of the tree does not demonstrate the systemic effect characteristic of antibiotic action and important to their economical use. It is too early to tell whether the cankers treated directly are only temporarily retarded in their development or whether they will be killed. More recent information suggests that the carrier oils used with cycloheximide in the earlier tests may have been inadequate. This could adversely affect the results.

Micromatic Studies Improve Blister Rust Control Methods

Research on microclimate in relation to white pine blister rust has permitted changes in control methods that can improve their effectiveness and reduce costs. This has been mentioned in earlier Station annual reports, particularly the one for 1960. Continuing studies of microclimate in forest stands are leading to refinements in control and to improved methods of growing white pine without serious blister rust losses.

In one study the differences in overstory transparency to light and heat radiation are being correlated with the growth rate of understory white pine and the amount of blister rust infection on these trees. These comparisons will show the understory condition necessary to get greatest white pine growth with least damage from blister rust in the high rust-hazard zones of the northern part of the Lake States. The influence of small openings in overstory canopies on the amount of blister rust on understory pines is also being studied to obtain a better definition of just what size opening is favorable or unfavorable to rust spread. The temperature, relative humidity, and radiation measurements being made in these two studies are valuable—both in explaining blister rust spread

FIGURE 45. — In bioassay work, large samples of tissues are required to determine whether an antibiotic is present in a given part of a tree. In this picture, the phloem above the treated portion of the trunk is being removed for use in a bioassay. The phloem is generally considered to be a downward conducting tissue in a tree.

and severity and in adding to general knowledge on the effects of the forest on local climates, which can influence tree growth and survival.

Local nighttime air currents are very different from those during the day; they are slower and are generated by dense, cold air settling and flowing downhill. Day air currents are turbulent, diffusing, and characterized by rapid updrafts. Therefore, the time of day that a spore is released into the wind for transport is very important in determining where it goes. Dr. Van Arsdel's laboratory studies have shown that the release of sporidia is limited to the nighttime period. Peak production of sporidia (the spore that carries the rust from gooseberries to pine) is 1:00 a.m., with almost no release of sporidia in the daytime period — even when temperature and humidity are rigidly controlled to highly favorable conditions. Profuse sporidial production begins the second night of favorable weather and continues for 5 nights. After that, the productive capacity of a given set of teliospores has been exhausted and further production is insignificant.

Jack Pine Stem Rust Control Study Shows Promise

Studies on the identification, epidemiology, and control of jack pine stem rusts are continuing. One new control study was established at the Higgins Lake Nursery near Roscommon, Mich., in cooperation with the Forestry Division of the Michigan Department of Conservation. This study is testing the effectiveness of two antibiotics in controlling seedling infection in nursery seedbeds. A second, larger study involving more test materials was established in 1961 at the U. S. Forest Service Nursery at Wellston, Mich.

A third study, established in 1960 at the U. S. Forest Service Nursery at Eveleth, Minn., has just been concluded. Each of four antibiotics tested there — phytoactin, cycloheximide and its semicarbazone and methyl hydrazone derivatives — reduced the number of infections on plots inoculated with the stem rusts the same year that the treatments were applied. Two inoculations made the following year to test the residual effect of the antibiotics produced no useful results because of high temperatures that prevented infection.

Work is continuing on field observations and greenhouse inoculation studies to improve our ability to distinguish between the several rusts that infect jack pine.

Races of the Blister Rust Fungus May Be Important

Research on the genetics of the white pine blister rust fungus received increased attention this past year. Previous work by the Station had shown that blister rust spore collections from different sources varied in their infection pattern on the *Ribes* host. Work now in progress is designed to determine whether races of the fungus also exist that vary in their ability to infect white pine. Grafted white pines, identical in their genetic constitution, have been inoculated with blister rust spores from widely varying sources. Differences in infection patterns between these different rust collections would indicate that the fungus does vary genetically in its ability to infect white pine. Such variation could have an important bearing on the breeding of pine resistant to this disease, as trees resistant to some races of the blister rust might be susceptible to other races. Although no results are yet available on this phase of the problem, considerable progress has been made in developing techniques to do the job.

Blister Rust Resistance Tests Established

In cooperation with the University of Wisconsin, the Station has established two field plots to aid in testing the rust resistance of the more promising white pine selections developed in the University's breeding program. One of these plots is in northern Minnesota, the other in the Upper Peninsula of Michigan.

Jones Disease Study Shows Negative Results

A limited amount of attention is being given to the severe injury and mortality of red pine in plantations on the Ottawa National Forest that is sometimes referred to as Jones disease. This disease has been present for many years and has virtually destroyed several plantations. Although a number of investigations have been conducted, the cause remains unknown. Current studies include one in which trees were inoculated with a fungus isolated from cankers on diseased trees. The results are negative. In another study, minor elements have been added in an effort to determine whether the disease is caused by a soil deficiency.

Some Attention Given to Root Rot Damage in Plantations

In recent years the Station has been receiving an increasing number of reports of damage to young conifer stands (particularly plantations) by

Armillaria root rot. At the present time the Station is able to devote very little attention to this problem. One sudy has been set up in collaboration with the Nicolet National Forest. In a portion of an area suffering a high level of Armillaria root rot, an effort was made to eliminate the more obvious food base materials that the fungus could use to invade nearby trees. The subsequent rate of infection on this treated area will be compared to a check area to learn whether this treatment has any appreciable effect on prevalence of the disease.

Staff members are also on the alert for *Fomes annosus* root rot. So far no evidence of damage from this disease has been found in the region, although the fungus has been reported as being here. The disease is causing serious damage in thinned plantations elsewhere, particularly in the southern and eastern regions where the problem is receiving substantial research attention.

Aspen Diseases — Only Hypoxylon Canker Studied

Current research on aspen diseases is limited to the hypoxylon canker problem. Other diseases (particularly heart rots and stains) are recognized as having a serious impact on the productivity and quality of aspen stands. However, since available resources for research on aspen diseases are not even adequate for the more important hypoxylon canker problem, work on these other problems cannot be justified at this time. Current work on hypoxylon canker is along three lines.

New Information Sought on Biological Aspects

The University of Minnesota, in cooperation with the Station, is studying some of the more basic biological aspects of hypoxylon canker, such as spore dissemination and factors influencing infection. This study has provided a substantial amount of new information. The most important question, however — how natural infection occurs — remains to be resolved.

Aspens Evaluated for Susceptibility

The Disease Division is also collaborating with the Institute of Paper Chemistry by evaluating the disease susceptibility of the various progeny produced in their aspen breeding program. On a rather long-term basis, this work should provide clues on the importance of the genetic factor in hypoxylon canker susceptibility and also indicate possible sources of resistance. It has already demonstrated that European aspen, *Populus tremula*, is as susceptible to infection as the native quaking aspen, *P. tremuloides*.

Progress Slow on Long-Term Ecological Study

The third area of study on the hypoxylon canker problem is the analysis and evaluation of data from the long-term field plot studies that the Station has been engaged in for many years with the objective of determining the influence of site and stand characteristics on infection levels. As has been mentioned in previous annual reports, these data were transferred to punchcards and a preliminary computer run was made. With this as a basis, a complex computer program has been selected which permits simultaneous analyses of several factors. A trial run with this program seems to indicate more promise of successful analysis than the simpler techniques used previously. To date, the press of other studies has delayed the careful appraisal of complex statistical factors needed before additional computer runs are made.

FOREST INSECTS

Forest insect research has been conducted by Federal agencies for about 35 years in the Lake States. Then, as now, research was a cooperative effort between the Forest Service, other Agriculture Department agencies, and various universities. Early collaborators, such as S. A. Graham, A. A. Granowsky, and L. W. Orr, set a high standard of research for forest entomologists. In 1954 the Federal activity was centered at the Lake States Station. Since then, staff and facilities have expanded somewhat, many professional journal articles and Station Papers have been published, and two USDA Technical Bulletins have been released — on the larch sawfly and the Saratoga spittlebug.

Research on forest insects in the Lake States has contributed to the development of various in-

secticidal and silvicultural control methods for several damaging pests. For example, methods have been developed to measure Saratoga spittlebug populations in susceptible red pine plantations, determine whether the trees are in danger of serious damage, and apply effective insecticidal control where necessary. These methods are employed annually on many acres of red pine plantations in the Lake States.

Research on other plantation insects is beginning to reveal useful management information on the relation between various sites and the susceptibility of the trees to insect pests. The goal of these studies is the development of recommendations regarding the risk of incurring an epidemic of a particular insect on a particular site — even before the plantation is established.

Intensive research on the spruce budworm has produced a better understanding of the relation between various spruce-fir stand conditions and cutting practices, and the susceptibility of the stands to damage by the spruce budworm. This information provides forest managers with a basis for deciding whether a budworm-infested area should be sprayed or cut.

During 1962 work was reoriented along the lines of three major projects: defoliator insects; plantation insects; and aspen, seed and cone, and shelterbelt insects. The work in each of the projects is outlined below.

Defoliator Insects

Spruce Budworm Studies Yield Information on Biology and Ecology

Research on the spruce budworm in Minnesota began in 1955. A major objective of the detailed life history studies was to learn whether the budworm population in this area differed from that in other parts of the country. If it did, new methods of prevention and control would have to be developed. While sampling for the various life stages of the budworm, new and improved sampling techniques were devised which are useful for observing population trends. Reports on these techniques have been published in Station Papers and various professional journals.

We can now conclude that the budworm in Minnesota is the same as that in the northeastern portion of the United States and adjacent parts of Canada and quite distinct from the form found in the Northwest. Detailed studies of agents affecting natural control of the budworm yielded results similar to those obtained in the Northeast. However, several species of parasites discovered here have not been reported elsewhere. No indicator parasite (one whose population trends would herald changes in the budworm population) was found.

A significant drop in the egg population in 1962 throughout much of the infestation area in northern Minnesota was apparently the result of cool, rainy weather which took a heavy toll of the adults before they could oviposit.

Other studies of the spruce budworm are beginning to yield results. For example, second-instar spruce budworm larvae floating on silk threads from overstory trees proved to be an important source of populations damaging to balsam fir reproduction. To learn more about the dispersal mechanism, second-instar larvae suspended on silk threads of various lengths were dropped in the laboratory, and their fall was timed. Average velocity of fall when compared with the length of silk thread exhibited a negative exponential relationship that was highly significant. Therefore, estimated dispersal distance can be calculated with these values for any length of thread, wind speed, or height above ground.

Spruce Budworm Takes Heavy Toll of Tree Growth

Although the spruce budworm has a long history of depredation in the spruce-fir type in North America, few data are available on which to base firm predictions of mortality and growth loss under various stand conditions. For this reason, a study was begun in which various spruce-fir stands were sprayed with DDT annually to control the budworm.

Measurements taken in these stands and on unsprayed check areas indicate that the budworm is indeed taking a heavy toll, especially among the dominant and codominant trees (mortality and top kill are widespread among these trees). In contrast, many of the overtopped and nonflowering intermediate trees remain relatively free from defoliation; others, though heavily defoliated, appear to be recovering. Some patchy mortality in the sprayed areas has also occurred. This "natural" mortality appears to be associated with the 1961 drought in northern Minnesota, since it is accentuated over areas of shallow bedrock.

Five years of observations have been taken in this study. The data now being analyzed are providing much useful information on the reaction of individual trees and stands to varying amounts of budworm damage.

Thinning May Reduce Spruce Budworm Damage

During the past decade or so, the spruce budworm has been controlled by aerial application of DDT in stands where mortality was imminent and profitable harvests were feasible. Although control has been generally successful, it is expensive, short lived, and sometimes accompanied by undesirable side effects on wildlife. For these reasons, studies or natural control of the spruce budworm and other forest insects have been given additional impetus. One of the simplest and most promising natural control possibilities is the use of silvicultural practices in spruce-fir to reduce the susceptibility of the stands to budworm epidemics. A series of cutting practice study plots was established in an area in northern Minnesota before the budworm became epidemic. As expected, the budworm did build up in this area, and the severity of the infestation that developed at each cutting level can now be determined.

Three replications of the study in three adjacent uniform blocks of spruce-fir, each about 25 acres, were selected for the tests. One block was cut with conventional clear-cutting standards. One was partially cut, leaving 60 to 65 square feet of basal area per acre in spruce and fir. A third uncut block was used as a check. Results are being critically analyzed, and indications are that thinning substantially reduces damage from the budworm (fig. 46).

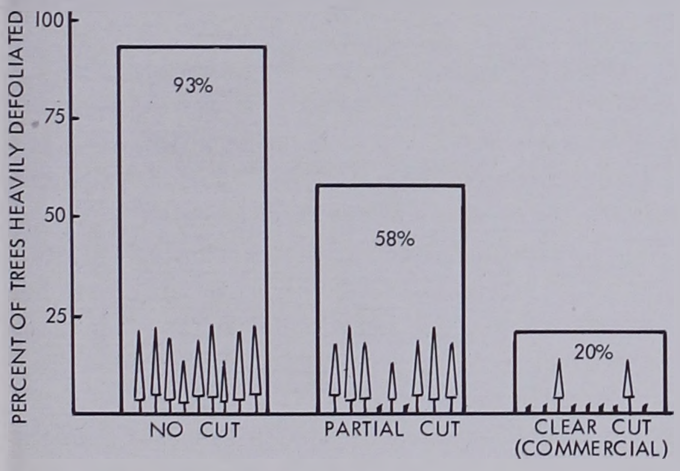

FIGURE 46. — Heavy defoliation by the spruce budworm is influenced by silvicultural practices.

Observations of spruce budworm defoliation in a study initially designed to test various thinning methods for growth response indicated that after 3 years of infestation, stands under the all-aged systems of management had the least damage. Stands under even-aged systems had more defoliation than did those on the uncut area.

Thinning Increases Breeding Sites For Jack Pine Budworm

Male cone clusters on jack pine are known to be important for survival of early instar jack-pine budworm larvae. It is also known that stand density is one of the primary factors in production of male cones. On the theory that measures which reduce production of these breeding sites (male cones) will help prevent population buildup in jack pine stands, a study was initiated to determine the exact relation between basal area and male cone production on jack pine. Five replications each of four stocking levels were sampled, using 1-foot-square wire seed traps to catch spent strobili.

In the second year (1961), male cone production increased somewhat over 1960 in the three highest stocking levels, but the increase in the lowest stocking level (30 square feet) was a tremendous 22-fold. Nevertheless, total production per acre in the 30-square-foot units is still the lowest because of the few trees present.

Aspen, Seed and Cone, and Shelterbelt Insects

In the past, the resources threatened by aspen, seed and cone, and shelterbelt insects have received relatively little attention from forest managers. Since there is virtually no heritage of research on these insects in the Lake States, initial efforts are being directed toward basic studies of their identification, damage potentials, and biologies and ecologies. Promising methods of natural and artificial control — the ultimate objective of the studies — will be investigated as rapidly as this background information provides some leads.

No particular biological relationship exists between the three groups of insects. Therefore, each is approached as a separate study. To date, little more than exploratory probing has been accomplished in the shelterbelt and aspen insect studies. An intensive study of seed and cone insects on red pine and white spruce was begun in 1962.

No Relationship Between Insects and Hypoxylon Canker Established

Although aspen is utilized to a greater extent than any other species in the Lake States, the supply still exceeds the demand. For this reason, protection did not seem to be a pressing problem in the past. However, the demand is for good-quality aspen, and it is now known that much of the aspen type consists of low-grade, deteriorating stands. Therefore, management efforts are being directed toward increasing the quality of the stands and preventing early deterioration.

The most serious protection problem in aspen is the highly destructive hypoxylon canker disease. Some preliminary work has been done on the possible relation between certain stem-boring insects and the disease. So far no clear-cut, direct relationship has been found. The boring insects by themselves do not appear to constitute a serious economic problem except in localized areas or under unusual conditions. Thus, the poplar borer, *Saperda calcarata,* generally ruins only occasional trees throughout the Lake States (fig. 47) but it has built up to very serious proportions in the Turtle Mountains of North Dakota.

Studies of two species of aspen twig borers were initiated in 1962 by the University of Michigan under a cooperative aid agreement with the Station. Results of these studies to date also indicate that the insects *Saperda concolor* and *Oberea schaumii* are not major factors contributing to the establishment of hypoxylon canker and early stand deterioration.

Limited studies of the poplar borer, especially along the lines of determining the natural factors that seem to prevent widespread epidemics, will be continued in the future. In addition, the relation between the borer and a reddish-brown wood stain will be investigated. Although the stained wood appears to be sound, it presents a utilization problem because excessive bleaching is required to brighten the wood sufficiently for paper pulp.

Many Insect Species Found in Shelterbelts

In the Northern Great Plains about 133,400 acres of successful shelterbelts have been established — largely to reduce the effects of wind erosion. Studies during the midthirties revealed a wide variety of potentially damaging insect pests in the shelterbelts. The droughty conditions present at that time favored the buildup of various wood borers, and many trees were lost. During 1960 an extensive survey of shelterbelt insects and diseases was again made. An even larger number of potentially destructive insect species was identified during this survey and reported in Station Paper 101 (see list of publications at end of report). Although none of the pest populations was high enough to be considered imminently damaging, their potential danger must be recognized.

Future studies will be directed toward: developing methods of predicting outbreaks, determining susceptibility of trees to insect attack under various growing conditions, and determining the natural factors responsible for holding potentially dangerous insects at low population levels.

Large Proportion of Cones Destroyed by Insects

With increased interest in the source of seed for future coniferous plantings in the Lake States, considerable effort is going into the establishment and maintenance of seed-production areas. Current-

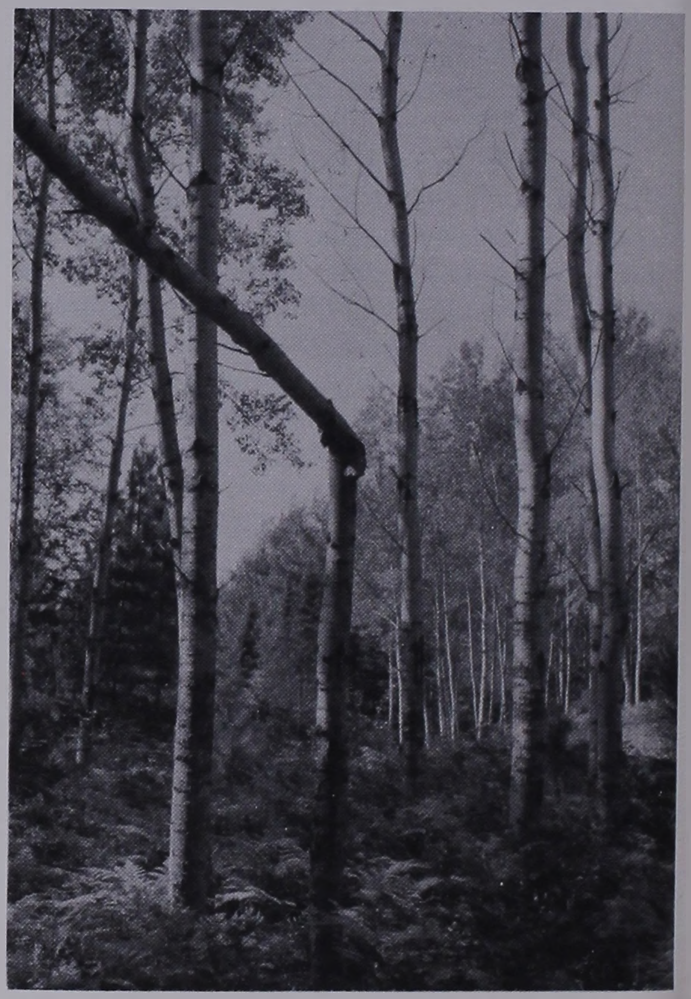

FIGURE 47. — Aspen weakened and broken off because of extensive tunneling by the poplar borer.

TABLE 4. — *Seed and cone insects in red pine, northern Wisconsin, 1962*

Tree no.	Tree ht. (ft.)	Total no. of cones	No. of infested cones	Percent of cones infested by:[1]						Percent of total cones infested
				Conophthorus resinosae	*Rubsaamenia* sp.	*Laspeyresia toreuta*	*Eucosma monitorana*	*Dioryctria* spp.	Unknown	
LAKEWOOD (NATURAL STAND)										
1	38	86	83	77	0	7	0	0	13	97
2	31	13	6	15	0	31	0	0	0	46
3	35	22	17	23	9	36	0	0	14	77
THREE LAKES (PLANTATION)										
1	27	32	23	6	50	3	12	0	22	72
2	27	95	63	23	34	0	5	1	6	66
3	26	36	23	14	47	3	14	0	6	64
4	32	22	17	59	18	0	9	0	5	77
5	30	35	24	11	43	0	6	0	11	69

[1] *Some cones were infested by more than one species of insect.*

ly, red pine and white spruce are the favored species. It is known that insects are exacting a toll from the seeds, cones, and flowers in these areas; but the species responsible, their relative importance, their habits and seasonal histories, and the feasibility of control are not well known.

During studies initiated this year, progress was made toward identifying the common pests of red pine and white spruce seeds and cones. Also, data were obtained on the distribution of the cone insects within a tree.

Table 4 summarizes the data collected from two red pine study areas, about 80 miles apart, in northern Wisconsin. The same species of seed and cone insects were found here as have been reported in southern Ontario. However, differences in importance of the species are apparent. A dipterous pest, *Rubsaamenia* sp., is very prevalent and damaging in northern Wisconsin. It attacks and kills the cones early in the season. In Ontario this pest was also common but not nearly as damaging. Also noteworthy is the relative uniformity of insect attack on the planted trees compared with the trees in the natural stand — even though both planted and natural trees were of similar height, spacing, and vigor. Although measurements have not yet been made, most of the attacked cones can be considered total losses as far as seed yield is concerned. Casual observations in other red pine stands in northern Wisconsin indicate that the magnitude of cone loss in the study areas was not unusual. On one seed-production area on the Chequamegon National Forest practically all of the second-year cones were destroyed by the red-pine cone beetle (*Conophthorus resinosae*) (fig. 48). No insects were found damaging conelets this year. All of the insects observed so far restrict their attacks to second-year cones.

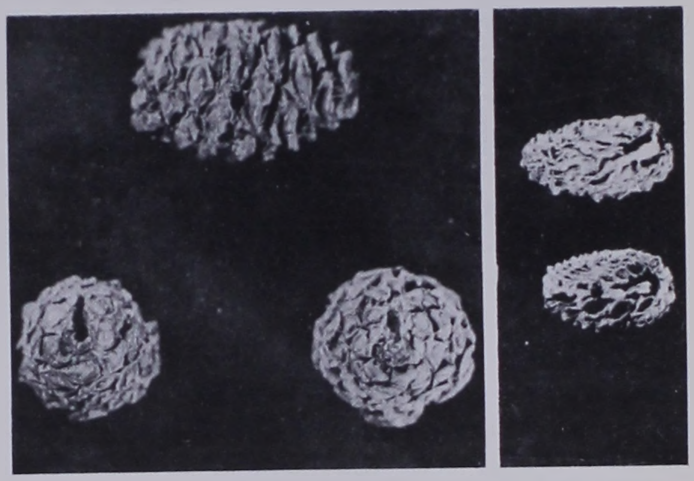

FIGURE 48. — Two-year-old red pine cones killed by the red-pine cone beetle. *Left*, note grooved base where cone has broken off from the pedicle; also, adult exit holes in center portion of cone. *Right*, interior of bisected cone.

Insect attack in white spruce cones was also very high this year. Of 321 cones dissected (scale by scale) from 5 white spruce trees, 225 were infested with *Laspeyresia youngana*, 89 with *Pegohylemyia anthracina*, and 40 with undetermined insects. Multiple infestations were common. Only 18 of the 321 cones were uninfested.

Among factors affecting the distribution and abundance of seed and cone insects, the distribution and abundance of cones are perhaps the most

basic. Many of the species depend entirely upon cones for their survival. Studies to date include detailed measurements of the distribution of cones within a tree. Knowledge of this is needed to develop methods for measuring insect prevalence, and especially to determine the success of artificial control studies.

Analyses revealed that in red pine, branch aspect alone had no apparent effect on cone production. On the other hand, shading (regardless of direction) not only reduced branch size but lowered the number of cones produced per unit of branch size.

On the average, heaviest cone production was found in the midcrown region of the trees, very few cones were produced on the branches near the ground, and about the top 10 percent of the crowns generally lacked cones. It was also found that the larger the branch, the greater the number of cones produced. When the two factors were combined (branch size and height of the branch in the crown), a highly significant correlation with cone production was obtained. These observations were made on open-grown trees less than 40 feet tall.

Analyses of the data will be continued to determine whether the distribution of the insects follows that of the cones within a tree. Data on the progression of life stages, natural control agents, etc., will also be available when the cone dissections are completed.

Among the incidental observations made during the fieldwork was the extensive mortality of conelets, apparently caused by a late spring frost. Careful measurements revealed that all of the conelets below a certain elevation were killed. If the entire crown of a tree was below this elevation, all of the conelets were dead. No other effects of the frost could be detected on the trees; vegetative growth appeared normal. This phenomenon may be an important consideration in choosing areas for the establishment of seed orchards.

Plantation Insects

During the past few years conifers continued to be planted in large numbers in the Lake States. Additional millions of acres are in need of planting. Plantations seem to be especially vulnerable to insect attack, and losses can be severe. In recent years the European pine shoot moth, an introduced insect, has become established in pine plantations in the region and is a major concern to plantation owners. Many plantations are also damaged by several other destructive insects, including the white-pine weevil, root collar weevil, Saratoga spittlebug, and various sawflies. All told, they are seriously jeopardizing the success of these plantations and pose a threat to any new plantations that may be established.

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FIGURE 49. — A 9-year-old red pine plantation on sterile subsoil and held back in growth by the European pine shoot moth.

Therefore, there is considerable interest in protecting the relatively large investment in plantations, and intensive insect research is underway to develop methods of controlling insect depredations. There is a need not only for controlling full-blown infestations, but also, and perhaps even more important, for methods of establishing plantations in ways that will prevent insect problems from developing later.

Before efficient methods of control and prevention can be devised for insect pests in the plantation environment, research must reveal the developmental and behavioral patterns that can be most easily manipulated.

European Pine Shoot Moth

Progress in understanding the fluctuations of European pine shoot moth populations in red pine plantations has been made. The major factors governing buildups and declines are tree vigor and weather. Native parasites play a minor role. Present knowledge about the European pine shoot moth is now being summarized for a major publication.

Tree Vigor Closely Related to Shoot Moth Hazard

During studies of European pine shoot moth populations, wide differences in rate of population

increase and severity of tree damage were found among various plantations in Michigan. The differences appear to be linked to tree vigor — the lower the vigor, the heavier the damage. Larval survival is apparently affected by tree health. Therefore, one very promising approach to prevention of damage is the establishment of plantations on sites that promote the vigor of trees. The identification of site factors related to persistent low and high damage levels is making it possible to draw up a guide to rating planting areas as to shoot moth hazard. Figure 49 shows a severely retarded red pine plantation growing on a poor site. This plantation will be ruined by the European pine shoot moth. In contrast, trees that are obviously growing well (say, 15 inches of terminal growth per year) are in less danger of serious, permanent damage by the shoot moth.

Biological Control Shows Promise

The hibernating European pine shoot moth larvae are susceptible to winter kill. This susceptibility is an important natural control of the pest. Sometimes low winter temperatures can wipe out a large segment of a shoot moth infestation. However, the weather factor is not amenable to artificial manipulation, and studies of it are largely descriptive.

On the other hand, it is known that shoot moth populations tend to be lower in the pest's European homeland than in the Lake States. Apparently, one reason for this is the greater effectiveness of parasites and predators in Europe. These biological agents *can* be manipulated, as was evident in 1960 when an introduced parasite, *Orgilus obscurator,* was found spreading into Michigan from its point of introduction in Ontario. Efforts were therefore stepped up to encourage the further spread of *Orgilus* in the Lake States and to colonize other European parasites as well (fig. 50). These efforts are beginning to pay off, because *Orgilus* is now established and appears to be spreading from most of the points where it has been released during the past 2 years. Moreover, a second parasite may have become established as a result of the program.

These promising results are stimulating more efforts in biological control. No spectacular decline in European pine shoot moth populations is expected, but even a small regular annual destruction of pests amounts to valuable protection.

Insecticidal Control Influenced by Weather

The first studies of the European pine shoot moth in the Lake States concerned chemical control methods. Unfortunately, an entirely satisfactory method has not yet been developed. The cryptic habits of the shoot moth make it one of the more difficult insects to control with conventional insecticides applied in conventional formulations. However, a continuing effort is being made to perfect techniques.

A pilot study, made this year in cooperation with the National Forest Administration, Region 9, was carried out, using DDT in a water emulsion applied with backpack sprayers at the rate of 2 pounds per acre. This comparatively low rate was made possible by hand-directed spraying, which permits better placement of the spray and the consequent relaxing of high dosages. Although the results did not indicate unqualified success, they were sufficiently encouraging to warrant additional tests. There is

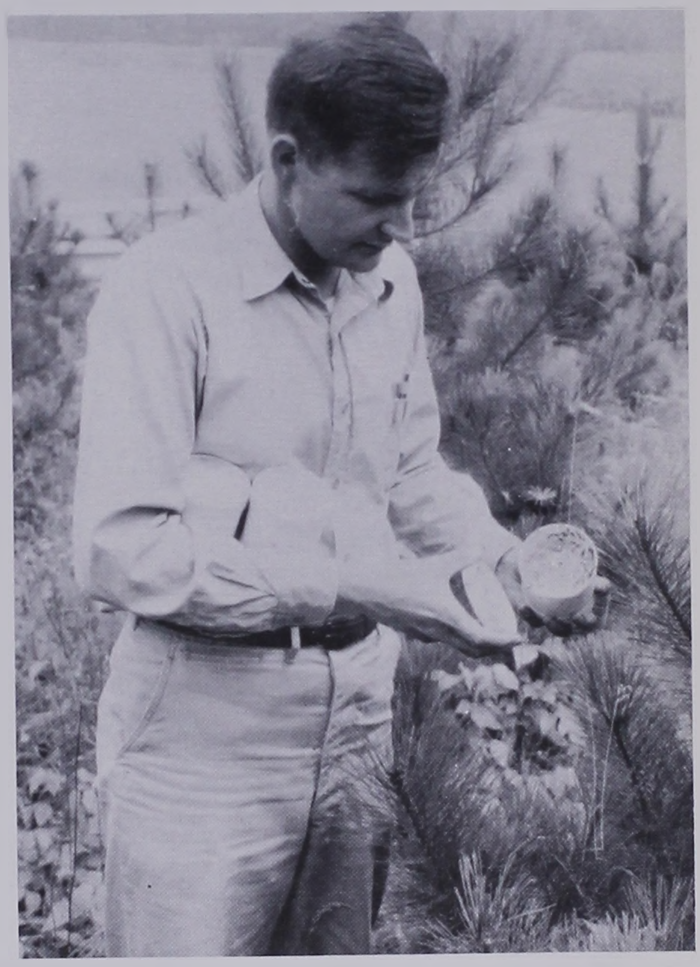

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FIGURE 50. — Dr. William E. Miller releases parasite wasps imported from Europe for suppressing the European pine shoot moth in red pine plantations.

reason to believe that the 1962 control attempt, which was directed against the migrating larvae just out of hibernation, gave poor control because unfavorable weather affected the deposition of the spray.

Rapid Survey Techniques Under Study

Recently, the scope of the plantation insect project was broadened to include other major plantation pests. One of the first tasks in this larger program is to develop or improve survey techniques for specific insects and determine the damage they cause at various population levels.

A sampling method seldom used previously but well suited to plantation insects is now being developed for several pests. It is called "frequency index" and is based on the fact that the proportion or percentage of sample units infested is a good measure of insect density. Simple determination of whether a sampling unit is infested is easier than a complete count of the insects. Sample units may be whole trees, halves, quadrants, or other parts of trees. The actual relation between the number of infested sampling units and the total number of units that could be infested can be developed for any pest. The main factor affecting the frequency index for a particular pest is the aggregative tendency of the pest.

When a reliable method for measuring an insect population is obtained, the next step is to relate the population to the level of host damage that will result. In most cases, this method is preferable to a traditional damage appraisal survey. Frequently when tree damage symptoms become obvious enough to appraise, the economic tolerance level has already been passed. Therefore, it is necessary to be able to predict the approach of the economic damage level by measuring the insect population. This method is being developed for several species of sawflies, the white-pine weevil, and the root collar weevil.

ulate interest in graduate study and on-the-ground training in research methods, the Forest Service has established several cooperative recreation research units at universities. In July of 1962 Dr. Hugh C. Davis joined the Lake States Station as leader of the unit at the University of Michigan, Ann Arbor. Dr. Davis recently served on the staff of the President's Outdoor Recreation Resources Review Commission. Since taking residence in Ann Arbor he has also served as recreation specialist on the Secretary of Agriculture's Task Force on multiple use of rural lands in the northern Great Lakes area.

Use of the Boundary Water Canoe Area

The study of the Boundary Waters Canoe Area of the Superior National Forest, which inaugurated the Station's program of recreation research, has been completed. In this study progress was made toward understanding both quantity and quality aspects of the public use of the Canoe Country.

Many People Do Ma

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No type is in the majority, but canoeists are th
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The most prominent feature of the distribution maps of every one of these various visitor types is the unevenness of use. A few places are jammed and large areas are unused or very lightly used. Figure 4 graphically expresses this in respect to access points. An even distribution would

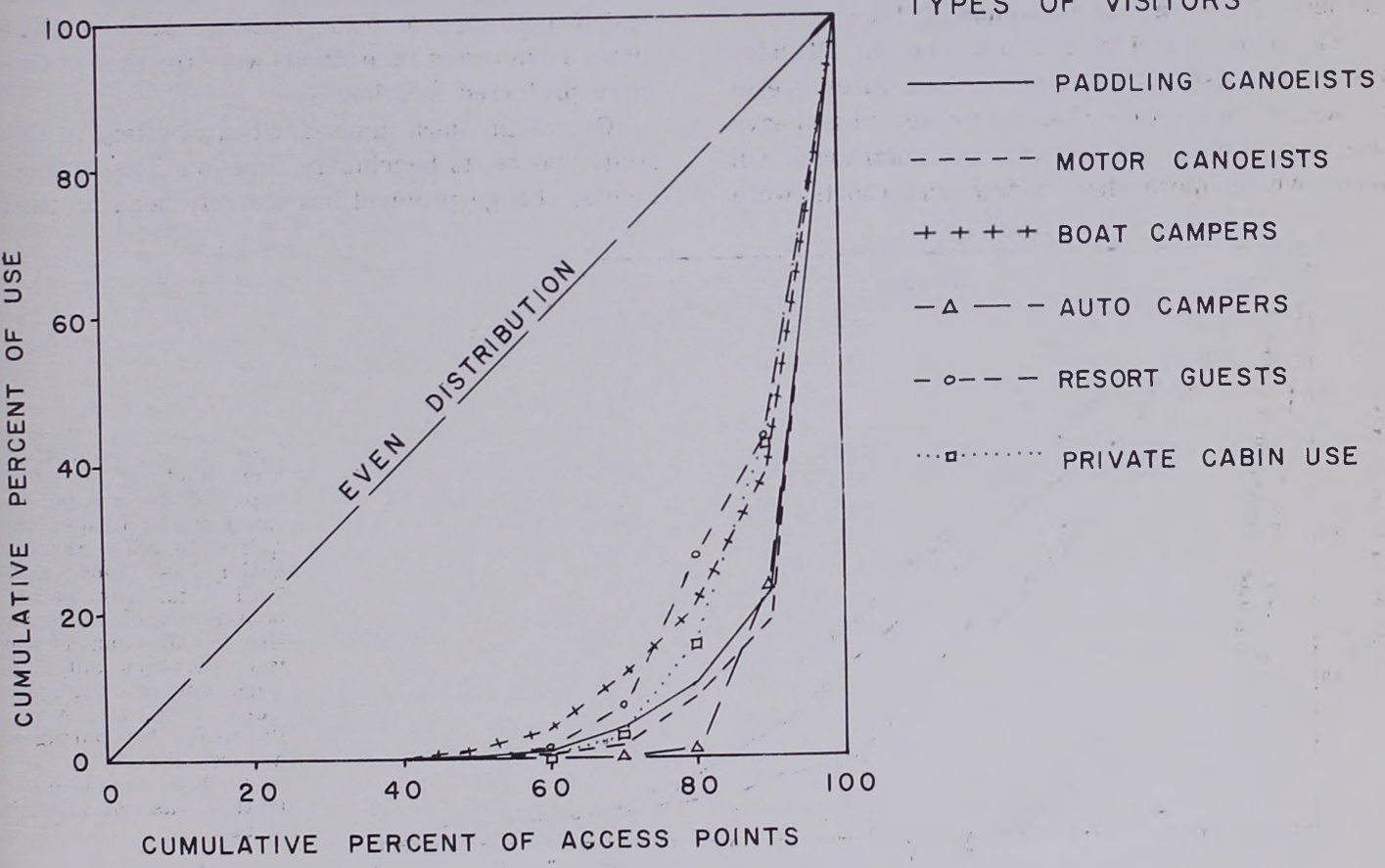

FIGURE 4. — Distribution of access-point use, 1961.

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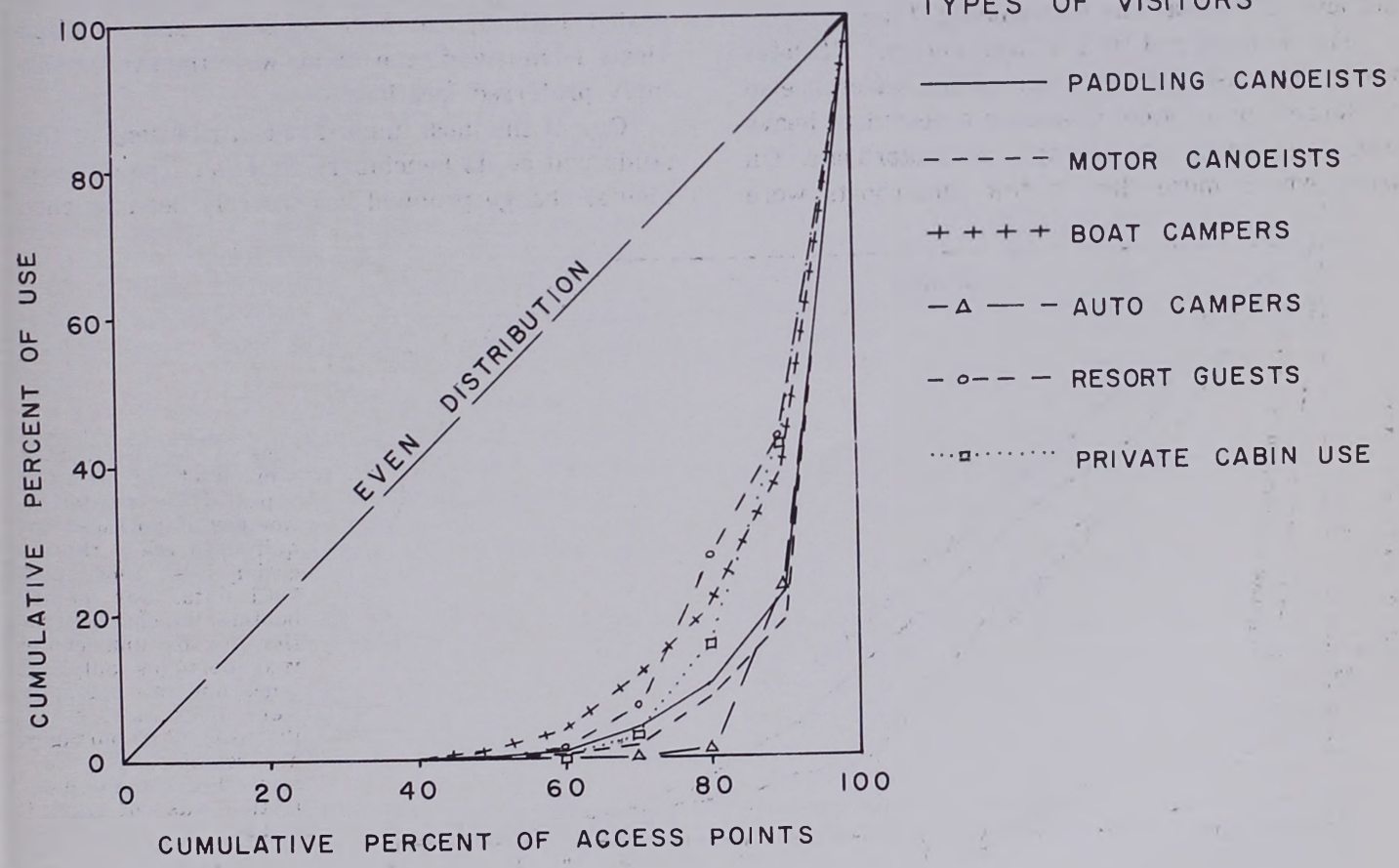

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Many People Do Many Things — In a Few Places

Four quantitative aspects of use were studied: amount, types, distribution, and trends.

The amount of use proved to be substantial — over 200,000 visits and almost 400,000 man-days in 1961. This appears to be about one-third of all overnight recreational use in the three counties making up the northeastern tip of Minnesota.

Many different types of visitors came to the area — canoeists, boat campers, campers who used the fringe campgrounds, resort guests, private cabin owners and guests, and one-day fishermen. No type is in the majority, but canoeists are the largest group.

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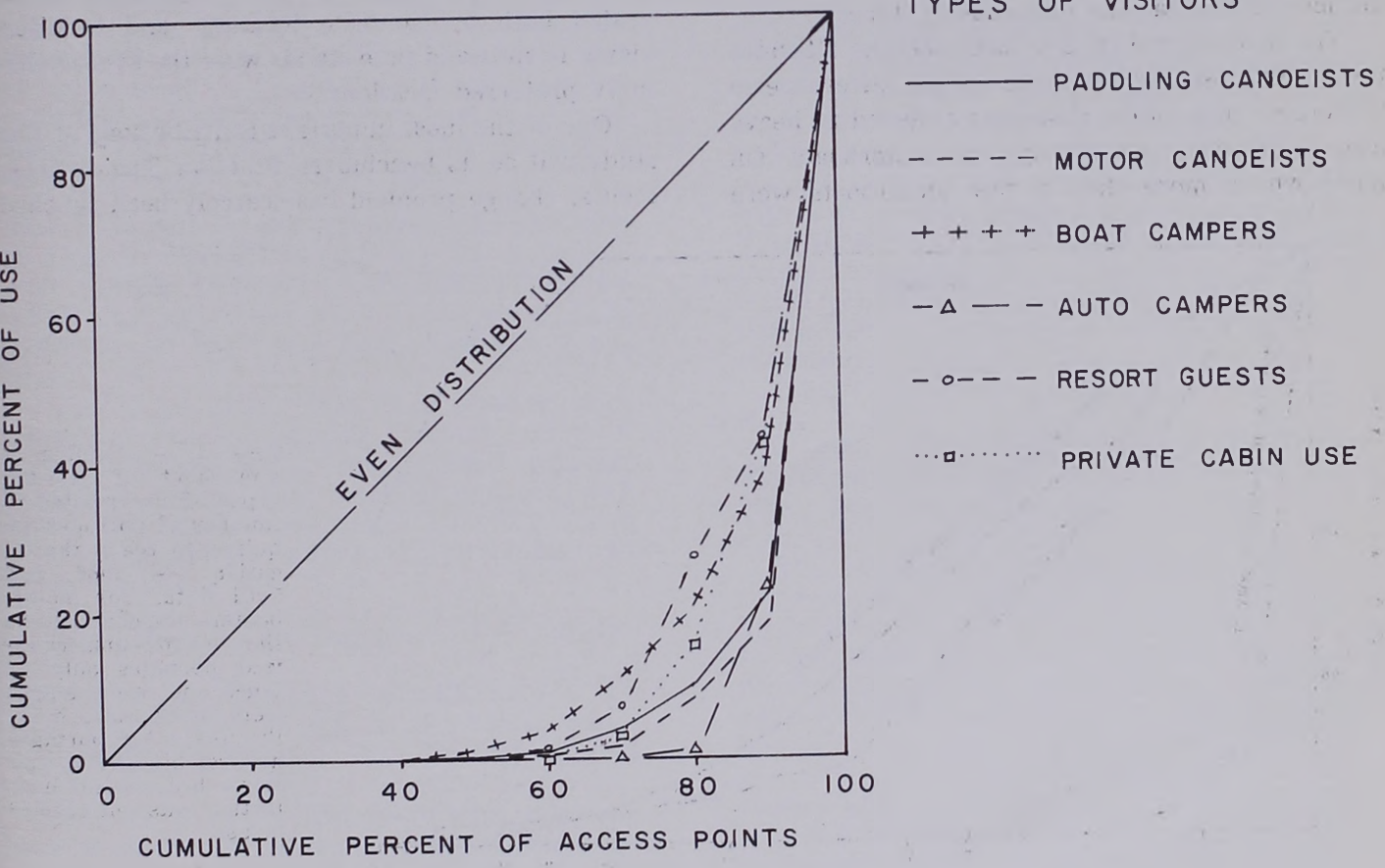

FIGURE 4. — Distribution of access-point use, 1961.

be graphed as a 45-degree line; instead, over half of the visitors in each class were concentrated at 10 percent of the more than 60 peripheral lakes and streams.

Canoeists roamed far beyond the access points, but unmechanized portages reduced boat use quickly. Figure 5 shows just how quickly.

Use has been increasing about 12 percent a year since 1946. At this rate, over one million visits would be tallied by 1976 — but what would have happened to the solitude?

What Makes a Wilderness?

The above projection stresses the importance of the quality aspects of the study. The wilderness characteristics of the area were cited as the reason for the decision to visit it by over 70 percent of the canoeists and half of the auto campers, but wilderness responses fell below half, and behind fishing and sometimes scenery, for other types. The importance of wilderness varied, and so did the boundaries of the wilderness in peoples' minds. Figure 6 maps the wide divergence between the small wilderness of the paddling canoeists (who prized wilderness most highly) and the large wilderness of the various noncanoeing types.

The amount and type of use, and the attitudes toward this use, explain much of the difference in wilderness perception. Canoeists objected to heavy use, and even more strongly to motorboats. On lakes where more than a few motorboats were present, the wilderness vanished for most canoeists, but they accepted heavier use on lakes where boats were absent. Motorboaters, in contrast, seldom objected to crowding and did not care what type of use they encountered (waterskiing excepted).

This conflict seems to be the main problem. Logging is allowed under restrictions to maintain natural waterfronts, and visitor objections to this practice are uncommon.

Wilderness Can Wear Out

Physical carrying capacity is another matter, and it is being investigated in a cooperative study with the School of Forestry of the University of Minnesota. Campsite deterioration in the Canoe Country is the focus of this research, for which fieldwork was completed in 1962. The relation of bedrock, soil, vegetation, slope, exposure, amount of camping, and number of years of use to the degree of deterioration, are among the factors under consideration. Figure 7 compares a sample plot on a badly compacted and eroded site with one only about 35 feet away which has a dense blueberry cover.

Campsite preferences were also studied, as revealed both by campsite locations and in interviews. Islands and pine stands were the overwhelmingly preferred locations.

One of the most important contributions of this study will be its benchmark function. The environmental change problem has scarcely been touched

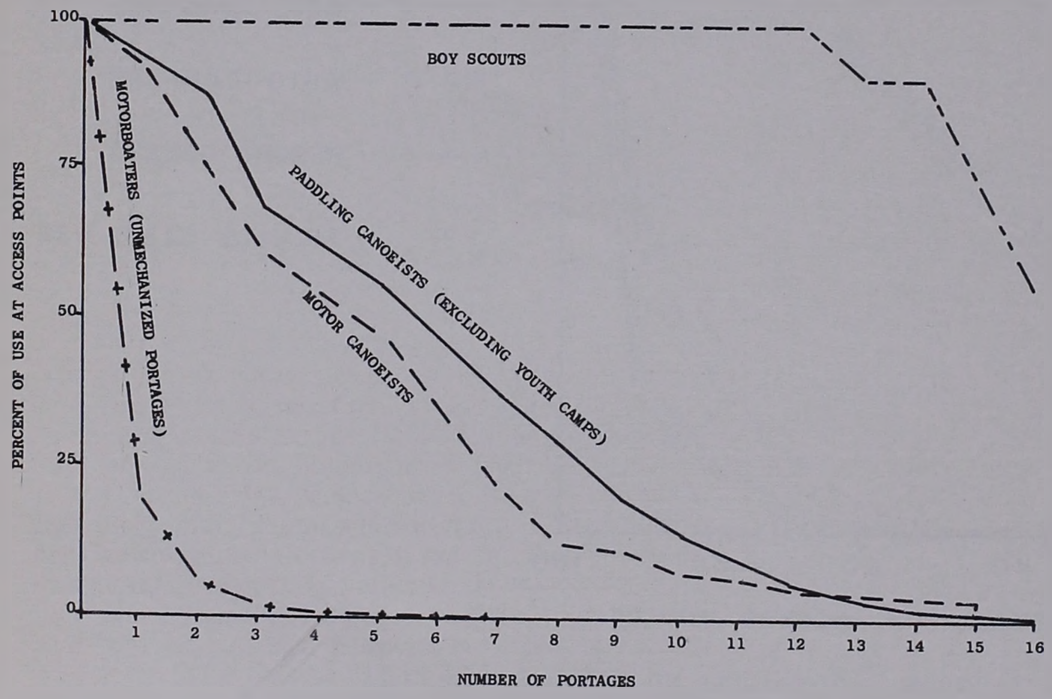

FIGURE 5. — Decline in amount of selected types of use related to number of portages required to reach the location — 1960 and 1961 data. For motorboaters, the chart shows the use of unmechanized portages only — truck and rail portages were much more heavily used. All portages are combined for canoeists because mechanization was not related to use.

LAKE STATES FOREST EXPERIMENT STATION
St. Paul, Minnesota

General Forestry — *Order No.*

U. S. Forest Service, Lake States Forest Experiment Station — R-293*

ANNUAL REPORT, 1961. (No series) 39 pp., illus.

(Following a brief review of Division activities during the year, the report concentrates on summarizing recent forest improvement research and suggests some of the opportunities for research in the future.)

Regeneration, Stand Improvement, and Harvest Cuttings

Buckman, Robert E. — SP-99*

THREE GROWING-STOCK DENSITY EXPERIMENTS IN MINNESOTA RED PINE — A PROGRESS REPORT. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 99, 10 pp., illus.

(Three experiments with common growing stock densities of 60, 80, 100, 120, and 140 square feet of basal area per acre are analyzed. Basal area growth varies but little over this range of densities, height growth not at all, but cubic-foot and cordwood growth tend to increase slightly with higher densities. This increase is most pronounced in younger stands.)

Buckman, Robert E., and Hubbard, John — TN-629*

A 5-YEAR PROGRESS REPORT IN A GROWING STOCK DENSITY EXPERIMENT IN 60-YEAR-OLD RED PINE. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 629, 2 pp., illus.

(This is the first report of a growing stock density experiment covering a density range of 30 to about 180 square feet of basal area per acre. The results show much in common with three other studies covering a narrower range of stocking and add information at higher and lower densities.)

Buckman, Robert E., and Lundgren, Allen L. — SP-97*

THREE PINE RELEASE EXPERIMENTS IN NORTHERN MINNESOTA. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 97, 9 pp., illus.

(Eighteen to twenty-five years after releasing pine from competing hardwoods on three experimental areas in northern Minnesota, the pines had responded most favorably on the full release treatments, intermediate on moderate release, and least favorably with no release. Release is one of the better investments in forestry.)

Church, Thomas W., Jr. — R-281

WHAT IS THE FUTURE FOR HEAVILY CUT HARDWOOD STANDS IN THE ADIRONDACKS? Northeast. Logger 10(7): 10, 11, 30, 31, illus.

(Most cutover hardwood stands in the Adirondacks are presently understocked. However, growth rates of both trees and stands are as high in the Adirondacks as in other northern hardwood areas. Species composition is changing rapidly because of past cutting practices. Commercial harvests are possible within the next 20 years. Continuous future cuts will depend upon adequate residual stocking.)

Godman, R. M. — TN-617*

SPROUTING OF NORTHERN OAKS REDUCED AFTER DEBARKING WITH SODIUM ARSENITE. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 617, 2 pp., illus.

(The percentage of stumps sprouting and number of sprouts per stump on trees treated with a 40-percent solution applied in a barked zone between frill girdles was significantly less than on untreated trees on the three oak species tested. There was no correlation with stump size in the ranges used and no effect on height of sprouts.)

Godman, R. M. — TN-628*

RED PINE CONE PRODUCTION STIMULATED BY HEAVY THINNING. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 628, 2 pp., illus.

(The percentage of trees bearing cones and the number of cones per tree were inversely proportional to the residual basal area in a twice-thinned, 51-year-old plantation. Maximum cone yield per acre should occur at about 80 square feet of basal area at the time of flower bud differentiation. Maximum cone yield per tree should be greatest at densities lower than those observed. Location of cones in the crown was only partially related to density, with half to two-thirds occurring in the middle one-third at densities of 60 to 140 square feet.)

* *Copies available for distribution.*

Godman, R. M., and Olmstead, R. L. TN-625*
SNOW DAMAGE IS CORRELATED WITH STAND DENSITY IN RECENTLY THINNED JACK PINE PLANTATIONs. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 625, 2 pp., illus.

(Ten inches of wet snow, accompanied by gusty winds, caused severe damage in jack pine plantations thinned the previous year. Frequency and type of damage were related to residual stand density and method of cutting. The percent of trees damaged decreased as basal area density increased from 30 to 120 square feet in compartments thinned primarily from below. Roughly twice as many trees were damaged in row-thinned compartments at comparable levels of basal area. Red pine with identical treatments was uninjured during the same storm.)

Roe, Eugene I., and McCain, Donald P. R-268*
A QUICK METHOD OF COLLECTING AND CLEANING ASPEN SEED. Tree Planters Notes 51: 17-18, illus.

(Opening catkins on branches previously brought indoors have their cotton collected with an upholstery-type vacuum cleaner. The felted mass is then placed in a 16-mesh screen, nested between one of 32-mesh (top) and one of 150-mesh, and agitated with a blast of air at about 50 pounds p.s.i. directed into the top screen from a length of rubber tubing. The clean seed collects in the bottom screen.)

Rudolf, Paul O. TN-615*
1961 FOREST TREE SEED CROP AVERAGES POOR IN THE LAKE STATES. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 615, 2 pp.

(Seed crops of the principal forest tree species are listed in percentage of a full crop for northern Minnesota, northeastern Wisconsin, central Upper Michigan, Lower Michigan, and north-central North Dakota. Although reports varied from species to species and locality to locality, this was generally a poor seed year in the Lake States.)

Rudolf, Paul O. R-286
REVIEW OF "SEED IDENTIFICATION MANUAL," BY ALEXANDER C. MARTIN AND WILLIAM D. BARKLEY, 221 PP., ILLUS., 1961. Forest Sci. 8:371.

Rudolf, Paul O. R-260*
COLLECTING AND HANDLING SEEDS OF FOREST TREES. U. S. Dept. Agr. Yearbook 1961: 221-226, 552-557. 1961.

(Condenses information for important North American forest tree species on time and methods of seed collection, types and processes of extraction, cleaning methods and extraction factors, kinds and effectiveness of storage, pretreatment methods for overcoming dormancy, and nursery sowing rates for species groups. Appendix table gives data for 86 species on seed production, weight, dormancy, and germination.)

Rudolf, Paul O., and Clausen, Knud E. R-264*
RED PINE SEED GERMINATION AFTER 30 YEARS OF STORAGE. Jour. Forestry 60:128-131.

(Red pine seed stored in sealed containers at low moisture content in a cold room, a fruit cellar, and an unheated attic still gave 4.1, 0.7, and 0.1 percent germination after 29 years' controlled storage and 30 years after extraction.)

Stoeckeler, Joseph H. R-291
REVIEW OF "DER FORSTPFLANZGARTEN (THE FOREST NURSERY)" BY HUBERT RUPF, SIEGFRIED SCHONHAR, AND MAX ZEYHER; BAYERISCHER LANDWIRTSCHAFTSVERLAG GMBH., MUNICH, GERMANY, 1961; 2ND ED., 242 PP., ILLUS. Forest Sci. 8: 262.

Tree Improvement

Buckman, Robert E., and Buchman, Roland G. TN-616*
RED PINE PLANTATION WITH 48 SOURCES OF SEED SHOWS LITTLE VARIATION IN TOTAL HEIGHT AT 27 YEARS OF AGE. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 616, 2 pp.

(Average tree height among eight regional groupings of Lake States red pine planted near Cass Lake, Minn., varied only 0.7 foot from the grand average of 39.8 feet in a source-of-seed experiment. Of the 48 individual sources tested, only one near Ashland, Wis., appeared to be significantly poorer than any of the others.)

Larson, Philip R. R-269*
THE INDIRECT EFFECT OF PHOTOPERIOD ON TRACHEID DIAMETER IN *PINUS RESINOSA*. Amer. Jour. Bot. 49: 132-137, illus.

(The influence of photoperiod on tracheid diameter was studied by independently exposing the buds and needles to different photoperiods. It is suggested that the effect of photoperiod is indirect and associated with the auxin production and distribution of the terminal meristems.)

Larson, Philip R. R-283
AUXIN GRADIENTS AND THE REGULATION OF CAMBIAL ACTIVITY. *In* Tree Growth (edited by Theodore T. Kozlowski), Ronald Press, New York, pp. 97-117.

(The development of the xylem is discussed in terms of (1) the initiation of cambial activity, (2) the formation of the annual ring, (3) the regulation of stem form. It is suggested that the

size and distribution of the xylem tracheids are regulated by auxin gradients originating in the foliar organs of the crown.)

Larson, Philip R. R-273*
A BIOLOGICAL APPROACH TO WOOD QUALITY. TAPPI 45: 443-448.
(A unifying concept is presented in which all variations in wood quality can be related to crown development.)

Rudolf, Paul O. R-285
VIEWPOINT OF A FORESTER ON FOREST TREE SEED LEGISLATION. *In* Proceedings of the Association of America Seed Control Officials Conference, New York, September 11-14, 1961, pp. 41-44.
(Presents "average view" of foresters, based on S.A.F. Seed Certification Subcommittee opinion survey, that some control of seed origin is desirable, but that legislation should be deferred until foresters are better informed and better able to make a decision on the need for it.)

Rudolf, Paul O., et al. SP-98*
REPORT OF THE SUBCOMMITTEE ON RESEARCH EVALUATION, COORDINATION, AND PLANNING. *In* Proceedings of the Fifth Lake States Forest Tree Improvement Conference, U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 98: 7-15.
(Subcommittee prepared an up-to-date roster of Lake States research workers in forest tree improvement and their specialties as part of the development of a national roster.)

Rudolf, Paul O. R-288
SEED PRODUCTION AREAS — A STEP TOWARD BETTER SEED. Second Central States Forest Tree Impr. Conf. Proc. 1962: 21-28. (Publ. by I11. Agr. Expt. Sta.)
(Describes the purposes of seed production areas and outlines the steps required for establishing and maintaining such areas for the principal Lake States conifers, red pine, jack pine, white spruce, and black spruce.)

Rudolf, Paul O.; Barber, John C.; R-287
Callaham, R. Z.; and Wakeley, Philip C.
MORE ON TREE SEED CERTIFICATION AND LEGISLATION, (A report of the S.A.F. Seed Certif. Com.) Jour. Forestry 60: 349. 350, 352.
(Refers to previous *Journal* statement by a group of foresters in the Pacific Northwest and points out certain misconceptions, answers some questions, and points to need for national consideration of forest tree seed certification and legislative question.)

Rudolph, T. D., and Nienstaedt, Hans R-265*
POLYGENIC INHERITANCE OF RESISTANCE TO WINTER INJURY IN JACK PINE - LODGEPOLE PINE HYBRIDS. Jour. Forestry 60: 138-139, illus.
(Evaluation of winter injury in hybrids and backcross progeny resulting from crosses of jack pine (*Pinus banksiana* Lamb.) and lodgepole pine (*Pinus contorta* Dougl.) indicated that resistance to this injury is a characteristic under control of multiple factors or polygenes, necessitating use of the backcross breeding method if a hybrid is to be produced possessing both winter hardiness and other desirable characteristics of the parent species.)

U. S. Forest Service, Lake States Forest Experiment Station. SP-98*
PROCEEDINGS OF THE FIFTH LAKE STATES FOREST TREE IMPROVEMENT CONFERENCE. Sta. Paper 98, 42 pp.
(Presents (1) brief papers on the practical potential of a regional tree improvement program and what the paper maker wants from the tree improver; (2) reports by seed certification and research subcommittees; and (3) descriptions of field stops at the Northern Institute of Forest Genetics and tree improvement plots of the Lake States Forest Experiment Station, University of Wisconsin, Nicolet National Forest, Institute of Paper Chemistry, and Consolidated Water Power and Paper Company. This conference provided the technical program for the Wisconsin-Michigan S.A.F. Section meeting.)

Wright, Jonathan W., and MP-906*
Rudolph, Paul O.
A BIBLIOGRAPHY OF FOREST GENETICS AND FOREST TREE IMPROVEMENT 1958-1959. U. S. Dept. Agr. Misc. Pub. 906. 93 pp.
(More than 1,300 publications on forest tree improvement published throughout the world in 1958 and 1959 are listed alphabetically by authors. Included for each is a complete citation and brief annotation as to species and subject matter. A subject-matter index completes the publication.)

Shelterbelts

Stoeckeler, J. H. PRR-62*
SHELTERBELT INFLUENCE ON GREAT PLAINS FIELD ENVIRONMENT AND CROPS. U. S. Dept. Agr. Prod. Res. Rpt. 62, 26 pp., illus.
(Presents data on effect of Great Plains field shelterbelts on wind velocity, evaporation, snow trapping, and soil moisture, and the reduction of wind erosion. Shows the effect of shelterbelts

on crop yields on 286 fields of small grains, corn, and cotton near shelterbelts of north-south and east-west orientation. Density, composition, and width of belts are discussed as well as recommended spacing between belts in parallel or grid systems.)

Soils and Water

Sartz, Richard S. R-289
THE COULEE EXPERIMENTAL FOREST — A NEW FIELD LABORATORY FOR SOUTHWESTERN WISCONSIN, Wis. Acad. Review 9(1): 1-5, illus.
(A popular-style article on research on the Forest and how the Forest came into being.)

Sartz, Richard S. R-267*
FIELD TRANSPORT FOR THE NEUTRON SOIL-MOISTURE METER. Jour. Soil and Water Conserv. 17: 27, illus.
(A three-wheeled buggy for transporting a Nuclear-Chicago neutron-scattering soil-moisture meter is described and illustrated. It is made from the front half of a girl's bicycle frame, a rear axle with heavy-duty bicycle tires, and a plywood carriage. It can be used over rough terrain. Cost was $64.)

Stoeckeler, J. H. R-277*
ANGLE-DOZER USED FOR TREE PLANTING. Jour. Soil and Water Conserv. 17: 178-179, illus.
(A small angle-dozer was used with good economy in making 30.5 miles of level, narrow bench terraces at an average cost of $12.20 per mile, or $12.57 per acre for a calculated 8-foot spacing between rows. The study was made in hilly terrain in southwestern Wisconsin with slopes up to 32 percent. Advantages and limitations of the method are discussed.)

Stoeckeler, Joseph H. R-290
A REVIEW OF "FORSTLICHE BODENKUNDE" BY S. A. WILDE, 240 PP. 1962. VERLAG PAUL PAREY, HAMBURG. (A translation and condensation of "Forest Soils"; translation by Theodor Keller, Felix Richard, and Helmut H. Krause.) Forest Sci. 8: 396.

Stoeckeler, J. H. R-292
PLANTING RESEARCH ON THE COULEE FOREST. Wis. Conserv. Bul. 27 (1): 10-11, illus.
(Describes a new program of reforestation research started in spring 1961 on the Coulee Experimental Forest near La Crosse, Wis., in cooperation with the Wisconsin Conservation Department. Planting trials the first year with 25,000 trees involved 11 species, 4 age classes, and 2 transpiration retardants planted on both cool and hot aspects of microsite.)

Weitzman, Sidney R-297
WHERE AND HOW WILL THERE BE WATER. Conserv. Volunteer 25 (145): 1-7, illus.
(Gives general picture of the water situation in the States of Minnesota, Michigan, and Wisconsin, and of the major problems in the northern bog and swamp area, outwash sand plains areas, and the loessal soils of the rolling unglaciated area of the Lake States. Proposes research in water yield, rehabilitation of eroded areas, snow and soil freezing studies, and water use.)

Weitzman, Sidney R-298
A REVIEW OF "GREAT LAKES BASIN" EDITED BY HOWARD J. PINCUS, 320 PP., ILLUS., WASH., D. C. Jour. Forestry 60: 880.

Forest Insects

Batzer, H. O. TN-618*
WHITE-PINE WEEVIL DAMAGE DIFFERS SIGNIFICANTLY BY SEED SOURCE ON TWO NORTHERN MINNESOTA JACK PINE PLANTATIONS. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 618, 2 pp.
(Plantations on the Chippewa and Superior National Forests both showed the same Wisconsin sources as having significantly more weeviling than their respective local sources. On the Superior plantation no Michigan source had significantly more damage than the local stock.)

Batzer, H. O., and Bean, J. L. TN-621*
SPRUCE BUDWORM DEFOLIATION CAUSES CONTINUED TOP KILLING AND TREE MORTALITY IN NORTHEASTERN MINNESOTA. U. S. Forest Serv., Lake States Forest Expt. Sta., Tech. Note 621, 2 pp., illus.
(The 1961 aerial defoliation survey showed 240,000 acres of spruce-fir type with extensive top killing and tree mortality compared with 96,000 acres in 1960. On 15 permanent sample plots balsam fir mortality averaged 2.3 cords per acre thus far during the budworm epidemic.)

Heller, Robert C., and Schmiege, Donald C. R-275*
AERIAL SURVEY TECHNIQUES FOR THE SPRUCE BUDWORM IN THE LAKE STATES. Jour. Forestry 60: 525-532, illus.
(Results of this study showed that spruce budworm defoliation can be classified by aerial observation. In addition, degrees of defoliation were correlated with larval insect populations.)

MacAloney, H. J. and Schmiege, D. C. SP-100*
IDENTIFICATION OF CONIFER INSECTS BY TYPE OF TREE INJURY, LAKE STATES. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 100, 41 pp., illus.

(Contains a key and brief descriptions of types of damage that will help the fieldman without specialized training in entomolgy to identify insects causing the damage. Also includes some brief notes on life history and habits, but control methods are not discussed. An identification chart and 39 illustrations are an important part of the report.)

Miller, William E. R-280*
DIFFERENTIAL POPULATION LEVELS OF THE EUROPEAN PINE SHOOT MOTH, *RHYACIONIA BUOLIANA*, BETWEEN EUROPE AND NORTH AMERICA. Ent. Soc. Amer. Annals 55: 672-675.

(Population levels of the European pine shoot moth in the United States appear to be higher than those in Europe. Available information suggests that greater host resistance and predation in Europe are involved.)

Talerico, Robert L., and Heikkenen, Herman J. R-274*
STEM INJURY TO YOUNG RED PINE BY THE EUROPEAN PINE SHOOT MOTH. Jour. Forestry 60: 403-406, illus.

(During a 5-year outbreak of the European pine shoot moth, the yearly frequencies of damage in four red pine plantings were studied. Forking was the commonest type of damage. From 3 to 17 percent of the trees completely escaped damage, and most of the remaining trees had damage correctable by judicious pruning. Only 7 to 15 percent of the trees had incorrectable, permanent damage.)

Wilson, Louis F. R-276*
INSECT DAMAGE TO FIELD-PILED PULPWOOD IN NORTHERN MINNESOTA. Jour. Econ. Ent. 55: 510-516, illus.

(Of several species of insects reared from balsam fir and black spruce pulpwood piles, *Monochamus scutellatus* (Say) was the most abundant and destructive wood borer. Volume loss from insect feeding ranged from less than 0.1 percent after one season of feeding to nearly 5.0 percent after two seasons of feeding. Insect attack varied by the type and location of the piles. Damage was least in shaded compact piles and greatest in loose sunlit piles.)

Wilson, Louis F. SP-101*
FOREST INSECTS AND DISEASES IN THE NORTHERN GREAT PLAINS: A SURVEY. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 101, 28 pp., illus.

(An examination of 325 areas in 1960 revealed more than 80 species of forest insects and diseases in North Dakota and South Dakota. These pests were found primarily in shelterbelts. Only a few pests were causing more than localized outbreaks.)

Wilson, Louis F. R-278*
A PORTABLE DEVICE FOR MASS COLLECTING OR SAMPLING FOLIAGE-INHABITING ARTHROPODS. Jour. Econ. Ent. 55: 807-808, illus.

(The device consists of a funnel-shaped muslin bag (10 feet in diameter) in a circular frame of ½-inch tubing. The arthropods are jarred from the tree into the bag with a pole. Manual vibration of the apparatus drives them into a jar at the apex of the bag.)

Wilson, Louis F. FPL-69*
THE YELLOW-HEADED SPRUCE SAWFLY. U. S. Forest Serv., Forest Pest Leaflet 69, 4 pp., illus.

(Gives current knowledge about hosts, damage, parasites, life history, and prevention and control of this forest pest.)

Wilson, Louis F. FPL-74*
WHITE-SPOTTED SAWYER. U. S. Forest Serv. Forest Pest Leaflet 74, 7 pp., illus.

(Discusses briefly the current knowledge on the life history, hosts, range, damage, and habits of the insect, and suggests means for its control and for preventing damage.)

Forest Diseases

Kessler, K. J. Jr. R-282
THE ENDOTROPHIC MYCORRHIZA OF *ACER SACCHARUM* MARSH. (Abs.) Phytopath 52: 738.

(Describes the anatomic relationship between sugar maple rootlets and the mycorrhizal fungus which dwells within them. The fungus is also described as it occurs growing through the soil. This is believed to be the first reported description of the soil phase of an endotrophic mychorrhizal fungus of a North American tree.)

Van Arsdel, E. P. R-279*
INTRODUCTION ON "SYMPOSIUM ON WEATHER AND PLANT DISEASE." Phytopath 52: 1095.

(The introduction contains a brief statement of the history of the cooperation of plant pathologists and meteorologists and some of the historical concepts of the relations of weather to plant diseases. Copies of the symposium papers (Turbulent Transfer of Fungus Spores, by Alice L. Robert, which tells how plant diseases are carried; and Weather, Space, Time, and Chance of Infection, by Paul W. Waggoner) are also available in limited quantities.)

Van Arsdel, E. P. R-272*
GREENHOUSE TESTS USING ANTIBIOTICS TO CONTROL BLISTER RUST ON WHITE PINE. Plant Disease Rptr. 46: 306-309, illus.

(Preliminary results of foliage sprays on cankered trees indicated that cycloheximide could be transported in the tree and could kill cankers. Foliage sprays on new shoot and needle growth were effective on small trees. Phytotoxic effects were serious in foliage sprays at 100 ppm on new shoots. Purified phytoactin was promising because it had a fungistatic effect.)

Van Arsdel, E. P. R-296
PLANT PESTS AND THEIR RELATIVES. *In* Bibliography of Agricultural Meterology, by Jen Yu Wang and Gerald L. Barger, 688 pp., illus., Univ. Wis. Press, pp. 343-380.

(Describes use of weather information in relation to plant disease spread. Lists over 1,000 references on the subject.)

Van Arsdel, E. P. TN-627*
FOREST OVERSTORY EFFECTS ON MICROCLIMATE AND RELATED WHITE PINE BLISTER RUST SPREAD. (Abs.) Bul. Amer. Met. Soc. 42: 739-740. 1961. Text of this talk was also published as Lake States Forest Expt. Sta. Tech. Note 627, 2 pp., illus.

(Five densities of aspen overstories were compared for microclimatic differences and the amount of rust present on pines on the various sites. Under overstories not too dense for pine growth the air was progressively drier as crown density increased. Differences between night and day air temperatures were less under denser stands. There was less rust infection on the pines under denser overstories. This was correlated with shorter saturated air periods.)

Van Arsdel, E. P., and Riker, A. J. R-294*
GROWING WHITE PINE WITH IMPROVED BLISTER RUST CONTROL BY USING CLIMATIC ESCAPE. Wis. Conserv. Dept. Pest Leaflet 5, 4 pp., illus.

(Presents recommendations for reducing white pine blister rust losses in Wisconsin by proper site selection and maintenance of favorable stand characteristics. The region is divided into four hazard zones based on climatic factors, and recommendations are presented for each zone.)

Wilson, Louis F. SP-101*
FOREST INSECTS AND DISEASES IN THE NORTHERN GREAT PLAINS: A SURVEY. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 101, 28 pp., illus.

(An examination of 325 areas in 1960 revealed more than 80 species of forest insects and diseases in North Dakota and South Dakota. These pests were found primarily in shelterbelts. Only a few pests were causing more than localized outbreaks.)

Forest Fire

Buckman, Robert E. TN-620*
TWO PRESCRIBED SUMMER FIRES REDUCE ABUNDANCE AND VIGOR OF HAZEL BRUSH REGROWTH. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 620, 2 pp.

(Two summer prescribed burns were far more effective than two spring burns in reducing the amount and vigor of hazel regrowth. Summer burning eliminated hazel regrowth completely on some subplots.)

Dieterich, J. H. R-271*
DEHAVILAND BEAVER WATER DROPPING TESTS. U. S. Forest Serv. Fire Control Notes 23: 73-77, illus.

(Water dropping from the DeHaviland Beaver is an effective means of initial attack on small fires in the lake country of northern Minnesota. The Superior National Forest has perfected an air tanker that delivers 125 gallons of water in a compact pattern and in sufficient quantities to either hold or control small fires in remote country. Modification of the drop opening in earlier models has resulted in improved drop patterns.)

Lake States Committee on Forest Fire Research. R-299*
A FOREST FIRE RESEARCH PROGRAM FOR THE LAKE STATES. U. S. Forest Serv. Lake States Forest Expt. Sta., (no series) 16 pp., illus.

(Reviews (1) information needed to improve fire control methods and develop uses for fire in land management and (2) research underway; lists specific research projects needed; makes recommendations concerning possibilities for cooperative research on specific parts of the fire research programs.)

Forest Wildlife

Krefting, L. W., Stoeckeler, J. H., Bradle, B. J., and Fitzwater, W. D. R-270*
PORCUPINE-TIMBER RELATIONSHIPS IN THE LAKE STATES. Jour. Forestry 60: 325-330, illus.

(In 1947-1954 a study of porcupine populations, sex ratios, weights, movements, and damage to second-growth northern hardwood-hemlock timber was made in northeastern Wisconsin. As many as one porcupine was found per acre, and one per 5 to 7 acres was not uncommon. In one study, area damage was estimated at 20.8 cents per acre per year.)

Forest Growth

Buckman, Robert E. TB-1272*
GROWTH AND YIELD OF RED PINE IN MINNESOTA. U. S. Dept. Agr. Tech. Bul. 1272, 50 pp., illus.

(Some 324 growth periods from 235 permanent sample plots provide a foundation for growth and yield tables for red pine in Minnesota. Net periodic annual increment in basal area and in cubic-foot, cordwood, and board-foot volume is predicted for ages ranging from 30 to 160 years; for stand densities from 60 to 180 square feet of basal area per acre; and for site indexes from 45 to 60. Rotation-long yield tables are then constructed for stands thinned at 5- or 10-year intervals to 90, 120, and 150 square feet of basal area per acre.)

Cooley, John H. SP-105*
SITE REQUIREMENTS AND YIELD OF PAPER BIRCH IN NORTHERN WISCONSIN. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 105, 11 pp., illus.

(Criteria were developed for the recognition of three classes of sites for paper birch in northern Wisconsin. Topography and silt-plus-clay content in the first 6 inches of soil were the principal indices. Clear cutting at or before 60 years of age was recommended for stands on poorer sites, and removal in a series of partial cuts on the better sites. Data indicated that yields in northern Wisconsin are about 25 percent lower than yields on comparable sites in Ontario.)

Forest Economics

Avery, Gene, and Meyer, Merle P. SP-96*
CONTRACTING FOR FOREST AERIAL PHOTOGRAPHY IN THE UNITED STATES. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 96, 37 pp., illus.

(Discusses technical aspects of forest aerial photography such as photo scale, camera focal length, type of film, time of year, flight planning calculations, and inspection of finished photos. Also covers the business aspects such as bid preparation and contracting. Presents "how to do it" in practical terms.)

Lundgren, Allen L. R-266*
A GRAPHICAL METHOD OF COMPOUNDING AND DISCOUNTING FOR USE IN FOREST VALUATION PROBLEMS. Jour. Forestry 60: 136-138, illus.

Using transparent overlays with different arithmetic time and logarithmic value scales, costs or returns plotted on semi-logarithmic graph paper can be compounded or discounted at common interest rates to any time, and the rate of increase of a given value function at any time can be determined.)

Quinney, Dean N. SP-95*
SMALL PRIVATE FOREST LANDOWNERS IN MICHIGAN'S UPPER PENINSULA — CHARACTERISTICS, OWNERSHIP ATTITUDES, AND FORESTRY PRACTICES. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 95, 20 pp., illus.

(Describes the small forest landowner population including its distribution as to type of owner, size of holding, objectives of ownership, forestry practices, problems, and responses to existing and proposed forestry programs. The considerable proportion of absentee owners and owners whose primary ownership objective is other than timber production suggests that for the Upper Peninsula the traditional approaches of public forestry programs may need to be revised.)

Schallau, Con H. SP-103*
SMALL FOREST OWNERSHIP IN THE URBAN FRINGE AREA OF MICHIGAN. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 103, 17 pp., illus.

(Despite the urban environment, the small private forest owners of southern Michigan could continue to produce an important share of the State's saw timber output. Urbanization and poor cutting practices, however, are two factors which will affect their level of output. Despite limited participation in the past, findings suggest that a strategic segment of the study area's forest owners might respond to increased publicity of forestry assistance programs.)

Forest Resources and Timber Production Statistics

Blyth, James E. TN-626*
PRODUCTION OF CHARCOAL AND CHARCOAL BRIQUETTES — LAKE STATES, 1961. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 626, 2 pp.

(Fifteen producers manufactured 65,122 tons of charcoal in 1961 in the three Lake States, 31 percent less than in 1956. Potential annual capacity is 100,000 tons, based on a 310-day operating year.)

Horn, Arthur G. SP-94*
PULPWOOD PRODUCTION IN LAKE STATES COUNTIES, 1960. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 94, 28 pp., illus.

(Compares pulpwood production and imports by States and species in 1960 with those of the previous year and 10 years ago. Shows 1960

production by species for the Forest Survey districts and counties in each of the three Lake States.)

Horn, Arthur G. TN-622*
VOLUME AND USE OF WOOD RESIDUES FROM PRIMARY PROCESSING IN MINNESOTA. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 622, 2 pp.
(Shows volumes and disposition by species, industry groups, and geographical areas.)

Horn, Arthur G. TN-623*
MINNESOTA PRODUCES 161 MILLION BOARD FEET OF LUMBER — 1960. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 623, 2 pp.
(Shows the 1960 lumber output by species, Forest Survey district, and selected counties in Minnesota. Also shows the number of sawmills that were actively engaged in processing logs to lumber in Minnesota. The 1960 production was down about 18 percent over that of 10 years ago, mainly because of a lessening in demand for jack pine and aspen lumber.

Horn, Arthur G. TN-624*
PRODUCTION AND IMPORTS OF PULPWOOD DECLINE IN THE LAKE STATES, 1961. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 624, 2 pp.
(Shows 1961 pulpwood production by species plus mill residues, with destination of wood produced in each State. Imports from other States and Canada are shown separately for the Minnesota, Wisconsin, and Michigan mills.)

Horn, Arthur G. SP-106*
PULPWOOD PRODUCTION IN LAKE STATES COUNTIES, 1961. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 106, 18 pp., illus.
(Shows pulpwood production for 1961 by county and species for each of the Lake States; compares production by species and District for several previous years. Data also show total timber cut for the pulpwood species in 1961 by species and Survey District.)

Stone, Robert N., and Chase, Clarence D. SP-102*
FOREST PLANTATIONS OF NORTHERN LOWER MICHIGAN. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 102, 30 pp., illus.
(Reports on the area and condition of forest plantations in the northern half of the Lower Peninsula of Michigan. By 1956 more than 660,000 acres had been planted to trees. About 517,000 acres were rated as acceptable forest plantations, but only the 317,000 acres without native tree overstories were growing satisfactorily. Release is badly needed on many areas. Large yields from improvement cuttings in plantations are possible. A method of determining allowable cut in plantations is given.)

Forest Utilization and Marketing

Neetzel, John R., and Otis, C. K. R-284*
FACED POLES MAKE BETTER BUILDING FRAMES WITH LESS LABOR. Forest Prod. Jour. XII: 527-530, illus.
(An estimated 2¼ million poles were used in some 45,000 pole-frame structures built in the United States in 1960. These poles were seldom straight, yet a plumb wall was desired. A degree of plumbness was obtained by cutting and shimming the poles. These and other joints between round poles and flat framing members were generally poor. The cost of attachment was high. Round poles can be greatly improved for pole-frame construction by facing one or two sides above the ground line. The cost of facing poles is much less than the extra cost of labor needed when setting the round poles and attaching framing members to them.)

Sutherland, Charles F. SP-104*
THE MARKET FOR WOOD PALLETS IN THE AUTO INDUSTRY — A CASE STUDY OF FORD MOTOR COMPANY. U. S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 104, 10 pp., illus.
(Describes kinds of pallets used in automobile manufacturing plants and by auto parts suppliers. Shows materials used in pallet making by sources and specifications. Outlines pallet marketing channels and practices, and comments on trends in use.)

Ward, James C. TN-619*
STACK DRAFTS PROVIDE OPTIMUM IGNITION AND COALING CONDITIONS FOR CHARCOAL PRODUCTION. U. S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 619, 2 pp., illus.
(Small fans in kiln stacks created accelerated ignition and coaling conditions in charcoal kilns. Stack drafts caused instantaneous ignition and reduced the normal coaling cycle by 25 percent. These improvements were obtained without a corresponding reduction in charcoal yields.)